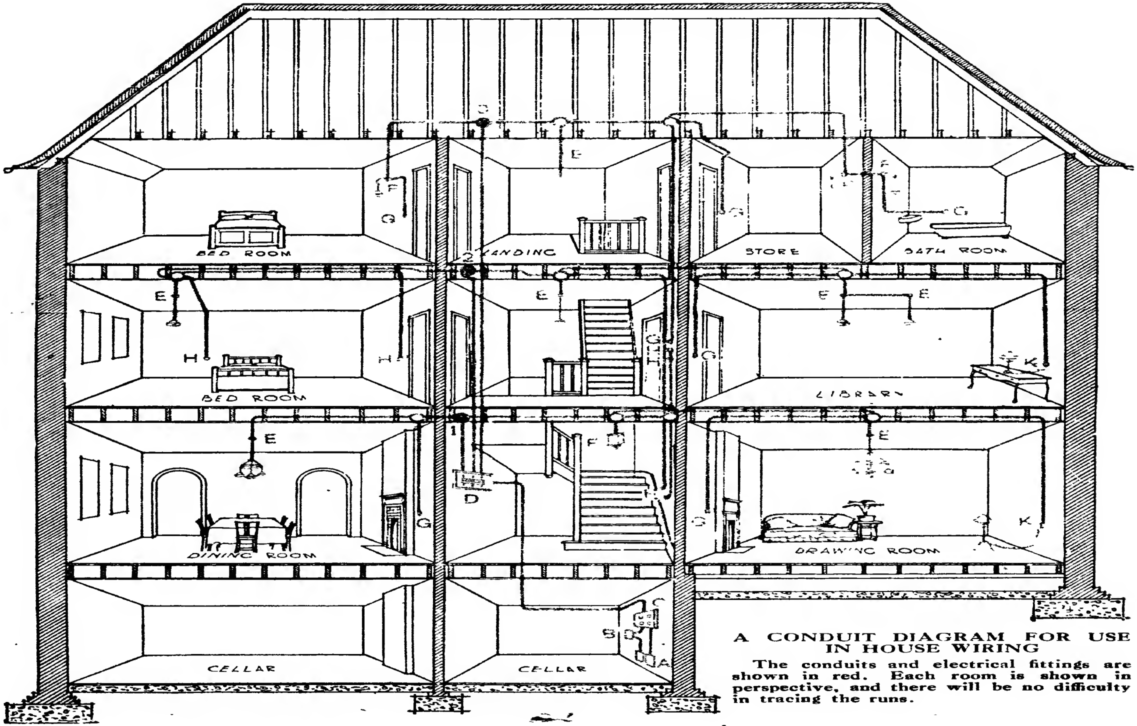
Electric Lighting—3.20



A CONDUIT DIAGRAM FOR USE IN HOUSE WIRING

The conduits and electrical fittings are shown in red. Each room is shown in perspective, and there will be no difficulty in tracing the runs.

Electric Lighting

A PRACTICAL GUIDE TO THE WIRING OF HOUSES AND THE INSTALLING OF ELECTRIC-LIGHT PLANTS

By

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Fully Illustrated by Line Drawings

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PREFACE

In this simply-written and practical treatise, which is based on original articles, etc., contributed to "Work," the Illustrated Weekly Journal of Handicrafts and Mechanics, but which contains also a large amount of matter now published for the first time, an electrical engineer of high qualifications and wide experience discusses the chief considerations preliminary to the installation of electric light in a dwelling-house, and next proceeds to explain fully how the wiring is planned and executed. The later chapters are especially valuable, since they are concerned mainly with the installation and erection of self-contained lighting plants using as power wind, water, steam, gas, or petrol. Mr. A. H. Avery will be happy to answer, through the columns of "Work," any queries relating to electric lighting that may be addressed to the undersigned.

THE EDITOR, "WORK,"
La Belle Sauvage,
London, E.C.4

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ELECTRIC LIGHTING

CHAPTER I

Introduction: Comparisons

To householders who may be considering any alteration of their present lighting arrangements and the relative claims of such rival illuminants as gas, acetylene, oil, or electricity, the question must naturally arise as to which illuminant is the most efficient and the cheapest in the end.

The transition from the ancestral rushlight to candles, coal gas, and paraffin oil, and more recently to pressure gas, acetylene, and electricity, indicates a remarkable tendency towards an ever-increasing brilliancy of illuminating power, which some, no doubt, would ascribe to the rapid march of civilisation, and others use as an argument to prove the slow, but sure, degeneration of our visual faculties. Whichever of the two theories may be correct, the fact remains that nobody at the present time is content to grope about between sunset and sunrise in the murky gloom which satisfied our forefathers.

The general desire, therefore, for a bigger and a better light has practically killed oil lamps and candles, except in isolated cases where considerations of portability, convenience, or artistic effect dictate otherwise. The points to be considered in weighing the claims of the remaining rival lighting systems are, in order of their importance: cost (including upkeep),

safety, and sanitation. It would be perfectly impossible to compare the advantages of gas or electricity under any one of these headings alone, and they must be considered collectively. To put the matter fairly and without undue bias, the advantages and defects of gas and electric light may be summarised thus, putting each on the same basis of candle-power and number of hours' light:

	Incandescent Gas	*Electricity*
Cost.	25 average c.p. for 250 hours, burns 1,000 cub. ft. of gas; average cost, 3s.	25 steady c.p. for 250 hours consumes 8 units of electricity; average cost per unit, 4d.; total cost, 2s. 8d.
Renewals.	Mantles at 3½d. each, eight in 2,000 hours (the life of one electric lamp); cost, 2s. 4d.	Usual life of metal filament lamps is 2,000 hours; cost per lamp, 2s. 3d.
Safety.	Considerable danger from naked lights. Leakage may cause explosions. Requires lighting with matches. entailing another fire risk. If blown out the unlighted gas may collect in poisonous and explosive quantities.	No matches required. Can be turned on or off at any point. No waste from by-passes. No smell. Described by fire insurance companies as "the safest of all illuminants when properly installed." If the lamps break, the light extinguishes itself instantly and does not leak.
Sanitation.	Consumes as much oxygen per burner as three human beings. Liberates carbonic oxide and vitiates the air. Tarnishes metallic ornaments, discolours ceilings, books, papers, and furniture.	Is hermetically sealed, emits no fumes, and consumes no oxygen. Cannot discolour ornaments of any description.

A frequent obstacle to the installation of electric light is usually the initial expense of the wiring, there frequently being the further handicap that there may already be gas fixtures in the building. But for the last-mentioned item, there would doubtless be 50 per cent. more houses wired up in every town having a public electricity supply than there are at present; but, owing to gas being already "laid on," the householder or landlord considers it hardly worth while to disturb existing arrangements, until the advantages become more evident after further reflection.

Perhaps the strongest incentive to making a change from gas to electric light is to be found in the possibility of accomplishing such conversion at a very moderate expense, and to the mechanic, amateur or professional, there should be no obstacle to doing the whole of the wiring himself, with the aid of the instruction given in the following chapters.

To wire a house successfully it is not absolutely essential for the worker to possess much electrical knowledge, although he should be conversant with certain elementary facts concerning the nature of the different kinds of electrical supply and with the terms used in measuring electrical quantities.

CHAPTER II

Systems of Current Supply

Two kinds of electrical supply are in vogue in Great Britain—the "direct current system" and the "alternating current system," known respectively in brief as "D.C." and "A.C." supply. In the first, the current flows steadily in one continuous direction, and is suitable for a greater variety of purposes than alternating current; but its distribution from the central station to the consumers' premises costs more than does that of the alternating current, and hence the last mentioned is more popular with the electric-lighting companies. Direct current can be used for lighting, heating, cooking, charging accumulators, plating, and other purposes; while alternating current may be used economically only for lighting, heating, and cooking. But as lighting and heating are the principal uses to which electricity is put in the majority of households, and for these purposes the D.C. or A.C. systems are equally well adapted, the kind of supply available is not usually of consequence. Some towns give a choice of both systems, in which case the D.C. supply generally has the preference.

Pressure.—Electricity is supplied to the consumer at pressures which vary in different parts of the country. Pressure is measured in "volts." A 200-volt supply is a general standard; but various other pressures are in use, ranging from 100 volts to 250 volts;

this does not affect the consumer, except that the greater the pressure the higher the voltage—the more careful must he be as to the insulation of his wiring, or "leakage" will occur.

Resistance.—To realise this, another electrical term must be introduced, namely "resistance." Metals such as copper, which is largely used for electric wires and cables, are very good conductors of electricity, and offer but a very small resistance to its path. Many other substances conduct freely, and it is essential, therefore, to confine a current in the path it is desired to flow, not only by directing it along a copper wire, but by covering that wire with some substance such as indiarubber, tape, cotton, and bitumen, all of which are "insulators," that is, offer a very high resistance to any current flowing through them. If the pressure is very high and this insulating covering on the wires gets damaged, its resistance is lowered at that point, and current leaks through. The higher the pressure of the supply, the more careful must the wireman be to secure good insulation everywhere.

Current.—The resistance of copper in an electric cable is extremely small as compared with that of its covering. Nevertheless, all copper cable possesses some little resistance, and as resistance where it is not wanted merely wastes the current, it is again of some importance to secure good joints everywhere if cables have to be joined together or to other fittings. Pressure in volts, balanced against "resistance" in ohms in any circuit, results in a certain flow of "current" measured in amperes. The relationship between the three is expressed simply in symbols, E representing pressure (in volts), R resistance (in ohms), and C current (in amperes). These are arbitrary units based on certain standards, which it is not necessary to go into here; but it is important for the wireman to be able to use

them in their proper relationship. The easiest way to commit them to memory is to write the expression as $\frac{E}{C\ R}$, and recollect that any one of these three factors, if unknown, can be calculated by placing the finger over its symbol and then reading off the remaining expression. Thus $E = C \times R$; $C = \frac{E}{R}$; and $R = \frac{E}{C}$. The value of two out of three terms must be known before the third can be calculated. The application of this formula, known as "Ohm's Law," will be illustrated on later pages.

Energy, and How it is Charged for.—One more electrical measurement, called the "watt," is of interest, because it is used to measure the amount of energy consumed on which the charges for supply are based. One watt = 1 volt × 1 ampere, and 1 watt supplied for 1,000 hours, or 1,000 watt hours, is the "unit" by which electric supply is charged up. In Great Britain the price per unit may be anything up to 9d. or 1s. There is no one standard charge, and even in the same town or borough electrical energy is not always charged at the same rate.

There are several systems of charging for current. By the "flat" rate, all the units of energy supplied are charged up to the consumer at the same fixed price per unit, irrespective of the total quantity used, the time of day or night, or whether the period of the year is winter or summer.

By the "rebate" system, all units supplied up to a certain prearranged number are charged at a maximum rate, and any further supply thereafter at a lower rate; this works out after the manner of "discount for quantities."

By either of the systems above mentioned, current

might perhaps be supplied at one price for lighting and another price for power, because power is usually wanted during the daytime, when the capacity of the electricity works is not taxed with a lighting load.

Supply may also be taken by the medium of "prepayment meters" of the coin-in-the-slot type, which include a device which automatically reduces the pressure and dims the light when it is time for another payment. In some cases current may be charged at a fixed rate based on the number of lamps installed, instead of being registered by a meter; then so long as the prearranged amount is not exceeded, the consumer may use his lamps as long as he likes. If the maximum current allowed is exceeded, a "limiter" inserted in the circuit causes the lamps to flicker and then go out.

The "maximum-demand" system of charging is another very widely adopted method of endeavouring to preserve a truer relation between the quantity of units supplied and the cost of producing them. To understand the need for such fine adjustments as a two-rate supply from one company, as compared with flat rates, for instance, it is necessary to appreciate that the items of expenditure, which go to form the total works' costs of any electrical undertaking, are subdivided into (*a*) "standing charges," such as rent, capital charges, salaries, wages, stores, and office expenditure, and (*b*) "production costs," which include fuel, repairs, and maintenance.

The costs under "standing charges" are independent of the units generated by the station, and go on all the time, whether the station is working at full output or not; they are proportional to the maximum capacity of the plant. Thus the size of any central station is largely determined by its consumers' maximum demand at any one time, to cope with which machinery of

an adequate size must be provided. It is to the company's interest, therefore, that instead of using a large current during a short daily period, the consumer should be encouraged rather to spread his current demand over a larger number of hours at a smaller consumption. In such cases a demand-meter is fixed on his premises, this indicating what the maximum demand for current has been at any interval during the quarter. He is then charged at so much per unit of his maximum demand for a given time per day, and the remainder of the supply at a much lower rate.

For instance, if a consumer is charged at one hour per day on his maximum demand at the rate of, say, 8d. per unit, and all units supplied thereafter at the rate of 4d. only, his quarterly bill will work out thus: Supposing the total units consumed during the quarter (90 days) to be 200, and the meter register shows the maximum demand at any time to have been 2 K.W. (2,000 watts). 2 K.W. × 1 hour per day × 90 days = 180 units, charged at 8d., or £6. Of the total 200 units consumed, 180 are accounted for above, leaving 20 only to be charged at 4d. each, or 6s. 8d., and the total quarterly bill will amount thus to £6 6s. 8d. Contrast this with the same quarterly consumption of energy, namely, 200 units, but now arranged so that at no time does the maximum load exceed 1 K.W. (1,000 watts); 1 K.W. × 1 hour per day × 90 days = 90 units at 8d., or £3. Of the total 200 units the remaining 110 are now charged at 4d., that is, £1 16s. 8d., making the total for the quarter £4 16s. 8d. only.

This advantage in limiting the total maximum current consumption is only secured naturally in towns where the maximum-demand systems are in force; but as they play such an important part in popularising electricity or otherwise, it is as well to appreciate their significance.

Relations between consumer and supply company.—The householder who decides to adopt electric light is recommended to acquaint himself with his exact position as regards the authorities, in regard to liability for maintaining his wiring in good order, and also to the observation of several points which may be the means of avoiding friction at a later date. The supply company, for instance, are not bound to supply current unless the wiring is carried out with due regard to safety, and has been passed as satisfactory by their inspector. They are quite within their rights in refusing to connect on a would-be consumer until he has complied with the necessary conditions. As it is to their interests to secure as many new consumers as possible, such refusal is never made on unfair or unreasonable grounds, and there remains nothing to be done but to bring the wiring into a satisfactory condition when such cases arise.

The supply company, however, is not entitled to discontinue the service once having connected it up, without due notice and reasonable justification; they are bound also to maintain their supply at the normal pressure, and their meters and fuses in proper order.

In a word, then, there are obligations on both sides. In general, the company is responsible for everything up to the meter, and the consumer is responsible for all expenses of wiring and maintenance from that point onwards.

The following outline of the usually accepted conditions of electrical supply, drawn up by the Incorporated Municipal Electrical Association, will serve as a guide in most cases. The conditions may, however, be amended in certain particulars to suit local conditions, and therefore the consumer should always procure any local rules and regulations issued by the company from whom he proposes to derive his supply.

CONDITIONS OF ELECTRICAL SUPPLY: EXTRACTS

Application for Supply.—The consumer should apply in writing to the company for a form on which to make application. Notice of the service being discontinued must also be made in writing.

Service Cables.—These are usually laid free of charge to the consumer's premises, if situated within 60 ft. of the main cables. For greater distances terms are by arrangement. Roads, paths, etc., broken up within the boundary of private property for the purpose of running cables are to be reinstated at the cost of the applicant for the supply.

Company's Property.—All cables, service fuses, meters, and demand indicators supplied and fixed by the company are sealed, and remain their property. No interference with such by any but the company's officials is permitted, and any damage occasioned to them by connecting on extra lamps or other apparatus must be made good at the consumer's expense.

Extensions.—Notice must be given in writing of any required extensions, and these must only be added after approval by the company's inspector.

Insurance Rules.—The premises must be wired in accordance with approved fire office rules. (*See* Chapter X.)

Charges.—The company fix and supply the meter of such type and size as they think desirable, and maintain same in good working order at a fixed quarterly rental. If the accuracy of the meter is questioned by the consumer, it can be officially tested. If incorrect, the company pay the expenses of test, and adjust the consumer's account for the current quarter accordingly. If the suspected inaccuracy is less than 2½ per cent., the consumer bears the expense of testing.

Besides the above extracts, there are certain pains

and penalties attached to any malicious cutting of electric cables, or alterations to the circuit, etc., in such a way as to divert the energy from being properly registered on the meter. These need not be entered into at length, as they will generally be found set out in the printed regulations which most electricity supply undertakings publish, and supply to their customers when the application for the service is made.

CHAPTER III

Choice of Insulating System

Three Systems of Wiring.—The point that next presents itself in logical order will be: What is the wiring of the premises going to cost, apart from lighting and maintenance expenses? The determining factor lies mainly with the choice of the system adopted.

Dismissing at the outset such systems as cleated wires, flexibles festooned through insulated eyes, and others which from their unsightly appearance or exposure to accidental damage find favour only in occasional instances, the selection resolves itself practically into a discussion of the relative merits of (1) wood casing, (2) conduit wiring, and (3) concentric systems. Any of these systems would be permissible according to fire insurance rules and the wiring recommendations now in force; and while there are strong advocates of each system to the exclusion of the two others, amongst even the most experienced of wiremen, it is a fairly safe rule to follow the multitude, and decide on that method which for the time being enjoys the greatest amount of popularity. There is usually some sound reason underlying the general adoption of a particular class of wiring, and whether or not its competitors be equally good, the popular system is the one most likely to be in favour with the authorities, and the one that will be saddled with the least stringent conditions as regards erection.

The necessity for any wiring system at all, it may be remarked here, is occasioned by the fact that the insulating coverings on the cables and wires lack the mechanical strength to resist the wear and tear of ordinary everyday treatment.

Wood Casing.—The history of the successive steps by which present-day protective methods have been evolved is interesting, but too long to relate. Wood casing as a protective covering to electric wires

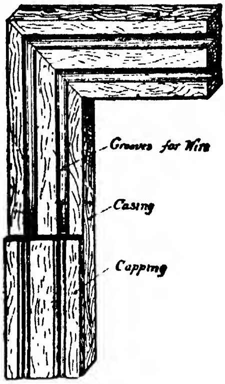


Fig. 1.—Example of Wood Casing.

held sway for a long time. It consists of strips of American whitewood with two channels cut for the reception of the wires, and a covering cap of reeded or moulded design to conform in style with the surrounding decorations. Such a system of wiring is shown in Fig. 1. It is cheap and easy to instal, but open to grave objections owing to its combustible nature and inefficient protection against damp, penetration by nails, etc.

Conduit System.—Metal tubes or "conduits"

represent the next step in progress, and at first were not wholly satisfactory owing to their high cost; partly, too, imperfections in manufacture prejudiced their general use. Improvements in this process, however, have now resulted in the production of both cheaper and better material; in fact, the finish and style of

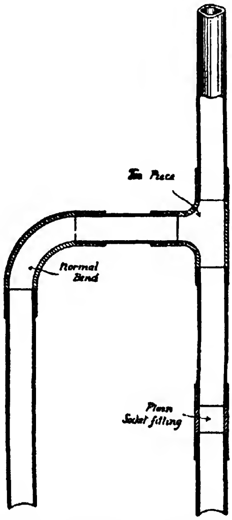


Fig. 2—Example of Socketing Conduit in Part Section.

the fittings of to-day, as represented in "Simplex" conduits, for instance, leave little to be desired. A typical example of conduit wiring is illustrated in Fig. 2. Here it is evident that not only is efficient protection against damp, nails, etc., secured, but, the conduit being itself incombustible and practically air-tight, reduces fire risks to a minimum degree of importance.

Concentric Systems.—A word or two must be

said about "concentric systems," since they may probably come into prominence in the near future. In this type of wiring the two conductors are concentric with one another (hence the name). The cable, in fact, consists of a rubber tube with one conductor inside and the other outside, the latter generally being left

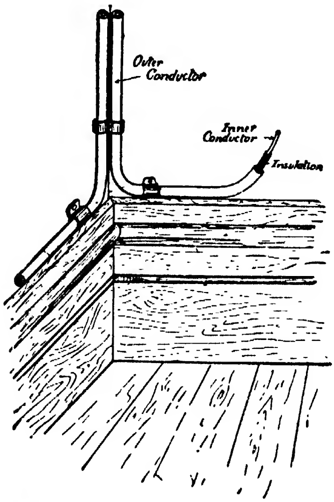


Fig. 3.—Example of Concentric Wiring.

bare. Such wires occupy the minimum possible space, and require no extra mechanical protection. Thus they can be fixed direct to the walls either by stapling to the surface, or by running them down a small chase in the plaster. Often such wires can be carried in an inconspicuous manner along skirtings, wall angles, chair and picture rails, etc., following any outlines of a decorative nature in a way which the less flexible casing or conduit is unable to compass.

A short section of concentric wiring, known under the trade name of "Stannos," is shown by Fig. 3. Its chief drawback lies in the special nature of the fittings required at lamp and switch points, which have to be designed to suit. Although favourably received by many lighting authorities, it is not sufficiently recognised perhaps to justify recommending its use for the wireman's first efforts. On the whole, "Simplex" will be found to meet the average requirements of the case so well, and is so easy to handle, that preference will be given to this system in describing wiring procedure.

Grades of Conduit.—The cost of erection cannot

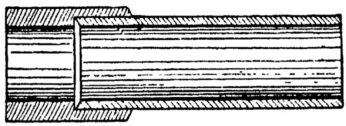


Fig. 4.—Plain Socket Junction for Conduit.

be gone into without considering the differences in quality of conduit that may be used according to its location; some grades are cheaper than others, and their use may conduce to economy in costs. In general, three styles of coupling up conduits and fittings are permissible, illustrated by the sections given in Figs. 4, 5, and 6. These are termed plain-socket junction, screwed junction, and screw-socket joints respectively.

Ordinary "socketing" conduit consists of metal tubes varying from 20 B.W.G. in thickness for ½-in. diameters of tube, up to 16 B.W.G. for diameters of 2 in.; while "screwed" junction conduit is made from heavier gauge metal varying from 17 B.W.G. to 14 B.W.G. Socketing conduit is made in three grades; "ordinary" tubing is made from metal sheet rolled to tubular form with a fairly close joint, and is the

cheapest grade of all. This tube answers well for surface work, under floorboards, and in dry situations generally; but must not be buried in plaster, as it is not moistu e-proof. The "brazed" conduit differs from ordinary in having the otherwise open joint brazed up neatly, and provides a waterproof and moisture-proof seam. This is slightly more expensive than ordinary open-joint tubing; but can be used under plaster as well as in all ordinary situations for house wiring. Lastly, there is the "seamless" grade, by which tubes are produced from the solid steel billet without joints of any description, and free from all roughness or projections likely to damage the wires

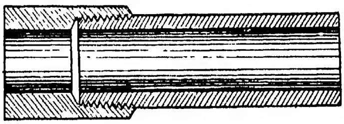


Fig. 5.—Screwed Junction for Conduit.

when being drawn through. It affords a maximum protection to the cables in every way, and is always employed for the best work. Naturally it is a little higher priced than either of the two other grades.

Plain Slip-in Sockets.—All these different classes of tubing lend themselves equally well to coupling together by means of plain slip-in sockets (Fig. 4), and can be obtained either in light or in heavy gauges; but heavy gauge is principally reserved for use when screwed junctions are employed, such as Fig. 5. Plain slip-in or socketing tube is the easiest to erect, as there is little else to do but cut the tubes to length, push them home in the fitting, and fix to the wall. But, unfortunately, this does not comply with the conditions often imposed by the electric supply authorities, that all such conduits shall be electrically as well as mechanic-

ally continuous. All conduits and fittings are heavily enamelled inside and out, and although usually very accurate in size, any slight variations in the " easiness " of the fit between tube and socket, quite insignificant, mechanically speaking, might add enormously to the electrical resistance of the tube system from end to end, or even interrupt continuity altogether. Should any part of the interior wiring develop a " fault " in such circumstances, that portion of the tube in contact with the fault would become " live," and if imperfect joints were present it would be insulated from earth, and therefore charged to a different potential. Any person at earth potential touching such a live tube would receive a smart shock, which could not happen if the tube were itself efficiently earthed throughout. Hence tube fittings and couplings that provide a good electrical connection are more likely to be passed by the company's inspector. In some localities no objections are raised to the use of plain socket fittings; but it is always as well to have a clear understanding on this point with the authorities before starting any work.

Screwed Joints to Conduits.—When electrical continuity is desired there are two ways of securing it; one by means of screwing the pipes and couplings together after the manner of gas or water barrel (Fig. 5), and the other by a special system of contact nipples screwed slightly taper and divided along one side by a saw-cut; on being screwed into their sockets or fittings after placing the ordinary tube into position with the enamel removed from its end, they close in and grip the latter securely, forming a sound electrical contact. Either screwed junctions or screw socketing answer the purpose perfectly; but the latter has the advantage that any wires already in position do not have to be twisted when tightening up a joint, as in

the former case, because neither the tubing nor the fitting turns round, only the screwed nipple. A further point in its favour is cheapness, because there is no outlay for screwing tackle required, and the labour involved in cutting and fitting threads is obviated.

If the object, therefore, is to wire up a house in a thoroughly sound manner, and not merely to cut all expenses to the last possible degree, "seamless" Simplex tubing with "screw-socket" junctions is the one which will give in the highest possible degree protection to the wiring and immunity from all danger to the occupier of the premises.

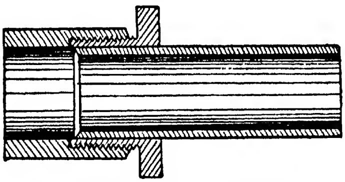


Fig. 6.—Screw-socket Joint for Conduit.

Cost of Erection.—With regard to estimating the actual cost of wiring any premises, it is customary to reckon this up at so much "per point." A "point" is regarded as any pair of terminal wires from which current will be taken, such as a ceiling rose, bracket, or plug connection. It is obviously difficult to give exact figures regarding the cost of wiring any house, owing to the fact that any two houses are hardly ever alike in all respects; but the average costs (pre-war) for private-house wiring were usually about 2s. 6d. per point for ordinary socket conduit, and about 4s. 6d. for seamless screw-socket tubing. This represented material alone, and was not inclusive of labour charges, lamps, switches, wire, or fittings. Using seamless screw-socket tubing throughout the installation, a good class of

insulated cables, and the usual plain fittings in the way of lamps, shades, brackets, and switches, the average result in a large number of jobs executed in various styles worked out at about 10s. per point for material, not including any labour in erection. This figure represented good-class work, with fittings of a plain, useful, and lasting character. All these prices can now be multiplied by from 2 to $2\frac{1}{2}$.

More elaborate fittings can be substituted if desired, and will, of course, affect the expense in proportion; but they will not enhance or detract from the efficiency of the illumination as a whole. Such deviations are a matter purely for individual taste.

CHAPTER IV

The Fittings

ELECTRICALLY speaking, one fitting is as good as another if well-made articles of British manufacture are purchased. It is the elaboration of brackets, pendants, switch-covers, and the like which are the main factors in the outlay, and the matter of "decor-

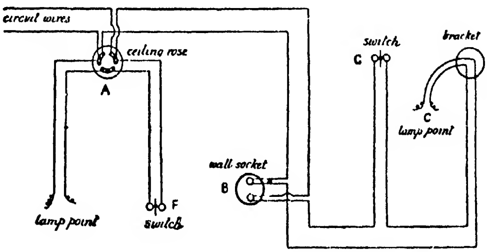


Fig. 7.—Typical Electrical Circuit in House.

ation" is one best left to the individual to decide according to his artistic taste and to the amount he wishes to spend. Information as to styles and prices are always to be gathered from manufacturers' catalogues, and it will suffice here to say just a few words concerning the nature of "fittings" in general—a term used to signify switches, brackets, fuses, wall-sockets, pendants, etc., as distinguished from the rest of the circuit composed of conduit and wiring.

The Fittings of a Simple Installation.—Take, for example, any simple electrical circuit such as shown by Fig. 7, typical of an arrangement found in most households. Current from the distribution centre (to be dealt with later) is conveyed by insulated wires through the steel conduit, and supplies a certain number of "points" on its way. At each of these points some kind of "fitting" is necessary, in order to adapt the lamp, heater, or other appliance connected to it; and, furthermore, each such apparatus requires to be controlled, that is, cut in or out of circuit by a further fitting, usually a switch. Thus, in the example given

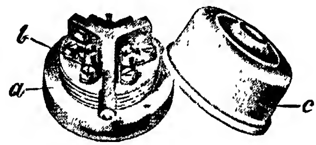


Fig. 8.—Ceiling Rose.

in Fig. 7, the electric cables serve the points A, B, and C, which are, in fact, outlets for current, A, for instance, may be situated in the ceiling, consisting of a ceiling rose, such as shown in detail in Fig. 8. This is a porcelain base *a* with three brass contact plates *b*, two of which are used for attachment to the service cables, the third plate forming a common junction for wires from lamp and switch respectively The cover *c* may be of porcelain also, or of stamped metal. The next point served at B is a socket fitting for a wall-plug connection, shown in detail in Fig. 9, where *a* is the porcelain base, *b* the socket terminals, *c* the plug terminals, *d* the socket cover, and *e* the flexible connecting wires. Such fittings would be useful in the case of heaters or portable standard lamps, table ventilating-fans, etc., where a permanent connection is not required.

The "plug" part of this fitting, also shown in Fig. 9, forms a part of the flexible wire connection, no switch usually being necessary, as withdrawing the plug from the socket serves the same purpose. Some lighting companies, however, insist on plug points being also under the control of a separate switch.

One more fitting is shown at C in Fig. 7. This represents an ordinary bracket for attachment to a wall; the insulated service wires run down the hollow metal tube to the lampholder at the end.

The Switch.—Both in points A and C the need

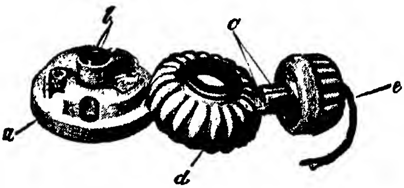


Fig. 9.—Wall-plug Connection.

arises to provide means of interrupting the current when the lamp is not needed alight, and this is done by an appliance familiar to nearly everyone—the switch (Fig. 10), which is shown at F and G (Fig. 7). In Fig. 10, *a* represents the porcelain base, *b* the terminal blocks, *c* the copper bridge, *d* the lever, *e* the metal cover, and *f* the quick-break spring. A good switch must possess two features; the current must not pass through any pivots or hinged portions, and it must interrupt the circuit smartly, separating the contact points quickly and widely; otherwise an "arc" will form across the contacts and soon burn them out.

The "quick-break" tumbler switch is the form universally adopted in house-wiring circuits for small currents. The essential part of the switch is a copper bridge piece, which, when pressed down by the switch

lever, connects together two flexible metal tongues forming part of the terminal blocks to which the service wires are attached. The connecting bridge is insulated from the switch-lever and cover, and the whole mounted on a porcelain base. The quick-break action is secured by a compression spring under the switch arm, which snaps the bridge wide open directly it leaves the terminal contact pieces.

The Lampholder.—This (*see* Figs. 11 and 12) consists of no less than eighteen different parts. There is a porcelain interior, carrying two brass terminal blocks, separated by an insulating bridge, to which the circuit

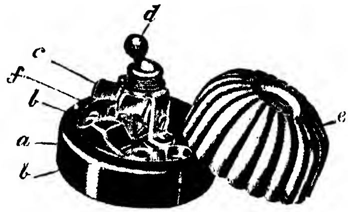
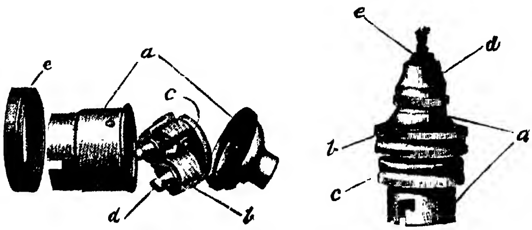


Fig. 10.—Switch.

wires are attached by means of pinch screws. These same blocks contain spring plunger-pins, which convey current to the lamp filament through the contact plates fixed in the end of the lamp cap. In Fig. 11, *a* represents the lamp body, *b* the porcelain interior, *c* the terminal blocks, *d* the spring contact pins, and *e* the milled cap nut. In Fig. 12, *a* represents the lamp body, *b* the milled cap cut, *c* the shade carrier, *d* the cord grip, and *e* the wooden interior of cord grip. In the lamp cap commonly used, shown in Fig. 13, will be seen two crescent-shaped contact plates, which are set in insulating cement, and are attached to the filament of the lamp; also halfway down the body of the cap are two small projecting pins. These engage with slots

formed in the lampholder body terminating in bayonet fashion, so that a slight turn given to the lamp causes the pins in the cap to lock in the slots, which being also slightly hooked, secures the lamp from dropping again by reason of the pressure from the spring pins behind. The porcelain lampholder interior is held by two recessed halves of the brass cover, a tongue in one and a slot in the other keeping the two halves together, and a further screwed ring like a locknut forms a means for securing the glass or metal shade. At the back of the holder is another brass cap with a coned interior



Figs. 11 and 12.—Lampholder.

and a split wood bushing, used to grip the leading-in wires insulating them from the holder, as well as relieving any strain on the terminal screws.

Lampholders are made to suit standard-size lamp ends termed respectively "Ordinary B.C.," which is $\frac{7}{8}$ in. in diameter, and "Miniature S.B.C.," measuring $\frac{5}{8}$ in. in diameter. The $\frac{7}{8}$-in. size is almost invariably used for house lighting. That part of the lampholder which receives the lamp shade is also standard as to diameter, namely $1\frac{1}{8}$ in.

Lamp Shades and Globes.—Shades are made in endless variety, both in enamelled iron, glass, porcelain, metal, silk, etc., and are fixed to the lampholder in the manner described above. Globes are frequently pre-

ferred on account of improved light distribution secured, and as the hole must then be large enough to pass over the lamp bulb, they cannot be fixed to the lampholder by the usual shade-carrier nut. An extension fitting or gallery is first fixed to the holder, and this latter takes the globe. As all the light thrown upwards from the lamp is lost, except by reflection from ceilings, some kind of shade is a necessity. For offices white opal shades are as efficient as any, while bell shades are more suitable for living rooms, and globes for halls.

Lamps.—Coming next to the important question of lamps, metal-filament lamps may be said to have practically ousted carbon filaments, on the ground of their far higher efficiency and the more pleasing colour of their light.

A 16-c.p. carbon lamp is found to require on the average 60 watts to maintain it at full incandescence; whereas metal-filament lamps of the same candle-power consume an average of 20 watts, this representing a clear saving of more than 66 per cent. in current consumption. They cost, however, about two and a half times the price of carbon lamps but they should last twice as long, so that on the basis of their respective lives, cost for cost, the ratio is 5 : 4; everything being considered, the advantages will be found decidedly in favour of metal filaments.

The drawback of the metal filament lamp is that the filaments, especially in the higher-voltage lamps, are exceedingly fragile, hence they must be treated with the utmost care; a slight shock in handling may break the filament when cold.

The lower-voltage lamps have the advantage of more robust filaments, and are much less likely to suffer from accidents; consequently, whenever it is possible to reduce the circuit pressure to 100 volts or

to 50 volts, the economy in renewals of lamps will generally justify the change. It is not feasible, however, to alter the circuit voltage economically on direct-current systems; but alternating current lends itself to a transformation from high to lower pressures with ease and economy by aid of an instrument called the "auto-transformer." When, therefore, the supply is

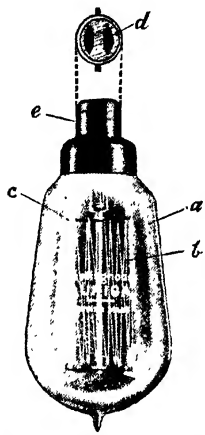


Fig. 13.—Metal Filament Lamp.

an alternating-current system of 200 volts or over, it will conduce to best efficiency to instal one of these transformers in the service mains, in order to reduce the house circuit down to a pressure of 50 volts or 100 volts.

A metal filament lamp of typical pattern is shown in Fig. 13. The glass bulb *a* contains the metal filament *b*, supported by struts *c* to minimise the risk of breakage as far as possible. The filament is attached to leading-in wires passing through and sealed into the glass bulb.

They are then attached to brass contact plates *d* fixed in insulating cement, which also holds on the brass bayonet-cap *e* fitting into the lampholder. The bulb is exhausted of air and hermetically sealed; if broken, the filament, if still alight, perishes by oxidation immediately the air reaches it.

CHAPTER V

Efficient and Economical Illumination

Preliminaries.—Having given a general outline sketch of the whole matter, it is assumed that work is now ready to be begun, and the householder wants to know "where to begin." From what has been said previously, the essential step as a preliminary is to write to the electricity supply authorities at the local generating station, and inform them that it is proposed to light a certain house in a certain street within their jurisdiction, applying for a copy of any regulations they may issue, and inquiring whether there are any special recommendations or restrictions to be observed. Particulars should be given as to the purpose for which current is required, whether for lighting, heating, or power, and they will furnish a scale of charges.

Positions of Lamps.—The requisite permission granted, copies of rules obtained, and other formalities satisfactorily complied with, the owner can proceed to go round his premises and estimate the candle-power required, as well as settle on the fittings for each room. This requires some experience and a liberal exercise of artistic taste to secure the very best effects. The decision as to situation of lamps, their candle-power, and style of fittings should be undertaken deliberately, and the opinion of the ladies in the establishment invoked, especially as regards the more decorative features. Do not jump to the conclusion that the

centre of the ceiling is the only proper place from which to hang a lamp, just because gas chandeliers have occupied that position from time immemorial. A brilliant light in the centre of a small room may possibly merely dazzle the eyes and fail to illuminate the apartment.

Efficient Illumination.—The ideal is to make the light itself inconspicuous, and yet obtain a thoroughly good diffused illumination. Artistic effects are never secured by a concentrated glare that meets the eye immediately on entering a room, to the exclusion or utter subduing of all else in it. Were it not that indirect illumination calls for a much greater candle-power than direct lighting, the most perfect system would be to light from reflection and diffusion alone. This can only be done, as in drawing offices, by inverted arc lamps, or in high-pitched dwelling rooms by means of tubular lamps (hidden from the eyes) arranged at intervals above and behind a heavy picture rail and reflecting their light from a well-whitened ceiling. Although this produces a beautifully soft, shadowless light, the nearest approach possible to artificial daylight, it is a method which cannot be commended where economy is desirable; three to four times the candle-power must be provided for indirect as compared with direct lighting, even in rooms with light-coloured walls and furniture.

Illumination Requirements of Various Rooms.—The difficulty of obtaining efficient and at the same time artistic lighting is enhanced in the case of small rooms, because the relative amount of light required is so small that one lamp usually suffices; the most natural position for such a lamp is, then, in the centre of the room, notwithstanding the artistic objections to that position. For instance, in a dining-room, where the table will naturally be found near the centre,

the best light is required immediately over it. In a library a moderate general illumination is required, with a more concentrated light on the reading table, such as would be provided for by a portable table lamp. A study or smoke-room would call for, say, two brackets, one on each side of the fireplace, well behind the lounge chairs, so as to avoid tiring the eyes of the reader. Drawing-rooms should have a soft light, but at the same time plenty of illumination, a case which may be met by a central chandelier (if the room is high-pitched) and one or two shaded standard lamps supplied by flexible wires and wall plugs. In an extra long room, excellent effects can be obtained by clusters of bracket lamps distributed round the walls at appropriate intervals. Bedroom lighting, on the other hand, must have quite different treatment; the lights require, as a rule, to be placed over the dressing-table, well to the window side, so as neither to throw the face of the occupant in shadow, nor to cast shadows on the blinds.

The position for hall and passage lamps depends principally on the length of the corridor, and the position of the staircases. Both the foot and the top of each flight of stairs should always be arranged so as not to be in shadow. An outside porch light is usually a great convenience when the first hall lamp is placed far back.

Position of Switches.—The position of the switch points controlling the lamps is of scarcely less importance than that of the lamps themselves. The best place for the switch that controls the light is usually just inside the door, where it comes immediately to hand on entering, and this is equally convenient for switching out the last thing on leaving the room. Where there is more than one light point in a room, or in the case of cluster lights, more switches may be grouped together to control and economise the lighting arrange-

ments. Thus a 3-light fitting may be controlled by two switches, one operating two lamps, and the other one the remaining lamp. This gives the option of one, two or three lights on at a time. In all living rooms, almost without exception, the most convenient position for the switches will be found just inside the door on the lock side; except where there are two or more doors each in use, in which case it might not be convenient to restrict the light control to one entrance only; but 2-way switches could be placed, one at each door. This gives "on and off" control at each door, irrespective of the position of the other switch.

In passages, halls, and bedrooms some deviation from the above general rule for switch-point position is allowable. Hall lamps, for example, should be so wired that they can be switched on or off from either the top or bottom of the stairs; for on coming into an empty house at night it is desirable to be able to switch on a light at once without groping about in the dark. Again, on retiring to bed, it would be most inconvenient to have first to extinguish the hall light, and then go up the staircase in perfect darkness, or else resort to a candle. Therefore hall lights should be controllable from both the hall and the upper landing.

Lights in long passages and corridors, for the same reasons, are far more convenient if they can be operated from each end at will. To get the full measure of convenience from electric light, these little matters, insignificant though they may appear, require to be carried out consistently at the outset, and once accomplished are a source of continual gratification afterwards. Unfortunately, they present a great contrast to many an installation wired by incompetent contractors, especially when price alone has been the consideration in securing the job.

In one's own house, where the placing of the furniture is not likely to undergo any great alteration, an extra switch or two in certain situations is often a great advantage. For example, in the case of bedrooms, it should never be necessary to get out of bed either to turn the light on or off; therefore the switch should be placed close by the bedside within easy reach of the occupant. To do away with the objection to entering a dark room to find this switch, corridors where the bedrooms open direct off the landing should be so lighted that a lamp comes either opposite or near to each bedroom door, and throws sufficient light within for the inside switch to be easily found.

Lamps are rated according to their candle-power; but the standard candle by which their light is measured has not the same light-producing power of the present-day commercial wax candle. The latter often gives two or three times the amount of light of a "standard" candle. There was, until quite lately, some want of agreement as to the real quantity of light represented by the so-called standard candles of various English and foreign authorities. The British unit, for example, was the light obtained from a spermaceti candle $\frac{7}{8}$-in. in diameter, burning 120 gr. of wax per hour; not a very accurate standard, as it would show 10 per cent. variation on occasion. A better standard was the Vernon Harcourt pentane gas flame, consisting of 7 volumes of gas to 20 of air, issuing from an orifice $\frac{1}{4}$-in. in diameter to a height of $2\frac{1}{2}$ in. The French unit, or "carcel," represented the light emitted by a lamp burning 42 grammes of colza oil per hour with a flame 40 millimetres high. The German unit was based on the illumination of a paraffin candle 20 millimetres in diameter, burning with a flame 5 centimetres high; while the American standard never seems to have been definitely fixed at all.

However, during 1909 an agreement was come to between the various authorities concerned, such as the National Physical Laboratory, the American Bureau of Standards, the Laboratoire Central d'Electricité of France, and the Gas Referees, by which it was decided that the new unit to be standardised should be termed "International Candle." It is practically the same as the English pentane unit and the French *bougie décimale*, the American and German units having been brought into line with it.

The problem of economical and efficient lighting is not at all an easy one to solve, because the effective amount of light given out by any lamp is modified very largely by such factors as reflection and absorption. To make this evident, consider two extreme cases:—first, one of a lamp placed in a room one side of which consisted entirely of a large mirror. The lighting value in such circumstances would be more than 90 per cent. greater than that of the lamp alone. Next imagine a dead black paper to be substituted for the mirror, and the light effect would immediately fall off to but a 5 per cent. increase or so on the mere actual candle-power of the lamp. In this way does the style and colour of the decorations and furniture affect the illumination due to any given number of light units. To take the case of wall paper alone, a white dull paper or distempered surface reflects about 80 per cent. of the incident light; according to the colour of the walls this figure may fall off until with dark brown or green papers 30 to 40 per cent. reflective values only are obtained. Deal walls reflect about 20 per cent. of the light rays; dark oak panelling reflects 10 per cent. or even less than that.

It is impossible to go into these matters in detail, and the wireman had better be guided mainly by the dictates of experience of others, classifying his lighting

into (1) low, (2) medium, and (3) bright illumination. Under average conditions, and in the case of small and average-size rooms, where the lamps would not be placed more than 8 ft. or 9 ft. from the floor, it will be a safe rule to allow 1 candle-power for every 6, 4, or 2 sq. ft. of floor surface for lighting classified as above. If more or less light is found advisable after trial, some latitude is obtainable in either direction without upsetting the wiring arrangements by the simple expedient of replacing the lamp bulbs by others of higher or lower candle-power. Low illumination is usually called for in such situations as scullery, pantry, coal-cellar, lavatory, passages, servants' rooms, etc. Medium illumination will serve for study, dining-room, library, hall, kitchen, and large bedrooms. Bright illumination is scarcely ever called for except in the drawing-room.

CHAPTER VI

Scheme of Distribution : the "Lay-out" Diagram

THE "lay-out" diagram is a plan of the wiring, showing all the lamps, switches, and fittings, from the main-service fuses to the most distant part of the circuit. It is not a scale drawing, nor does it show the exact relative position of the points; but it is a key or reference diagram to the various runs and circuits which branch out from the distribution centre.

Distribution-board System.—Modern wiring is now carried out on the "distribution-board" system. The service cables, after leaving the fuse boxes, are continued to a distributing centre in an unbroken run by main cables large enough to carry the whole of the current required by all the lamps or other fittings in use; and from this point, which should be placed as near the centre of the various lamp positions as feasible, smaller wires branch off to supply individual sets of lamps. By splitting up the supply in this fashion, several advantages are secured. For instance, the failure of a fuse does not throw the whole house in darkness, but merely extinguishes the lamps on that particular branch. Again, the fall of potential, DI volts lost by the resistance of the cables, is equalised when the lamps are fed at one pressure from a central point, because all the radiating branches are then comparatively short. This is made clearer by reference to Figs. 14 and 15.

In Fig. 14 the lamps are shown all wired on one length of cable. *a* represents the mains, *b* the fuses, *c* the switch, and *d* the lamps. Naturally, the lamp nearest the service mains is being supplied with current at full pressure, while the most distant lamp is clearly robbed of some of its light, because a certain proportion of the pressure is abstracted on the way, owing to some resistance, however small, always being present in the cables. If this resistance is known, and also the value of the current which is flowing, the dissipated volts are easily calculated by applying Ohm's law $E = C \times R$. This is termed the "volt drop," and in conformity with modern wiring rules must not

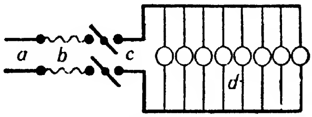


Fig. 14.—Lamps Wired on "Tree" System.

exceed 2 per cent. of the total pressure, plus a fixed allowance of 1 volt. Thus in a 200-volt supply, the pressure at the most distant lamp must be at least 195 volts, for 2 per cent. of 200 volts is 4 volts and 4 + 1 subtracted from 200 leaves 195 volts. Similarly, on a 100-volt circuit, the maximum drop in volts at the farthest lamp must not exceed 3 volts.

The Volt Drop.—This point is of some importance, as cable sizes are chosen more with reference to the permissible volt-drop than to their actual current carrying capacity. For instance, if all the lamps connected as in Fig. 14 required a total of 12 amperes, a 3/20 S.W.G. cable will safely carry this without overheating. But every 10 yd. of lead and return circuit, or 5 yd. linear distance, will offer sufficient resistance when worked at this current density to cause a fall

in pressure of one volt. On a 100-volt circuit, therefore, the length of one run of such cable would be limited to 15 yd. distant from the point at which it started, because this is the maximum distance it could run without exceeding the regulation 3 volt drop provided for above. Should the last lamp in any circuit be situated at a distance greater than 15 yd. from the starting point, it would then be necessary to employ a larger section of cable, working it at a current density lower than its real capacity, in order to keep the volt drop within limits. This, of course, would not be economical.

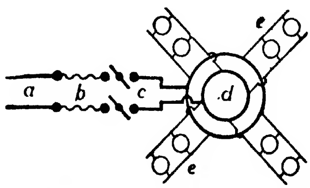


Fig. 15.—Lamps Wired on Distributing-centre System.

A comparison should now be made with the same number of lamps, but arranged as in Fig. 15, which is typical of the distributing-centre system. In this figure, *a* represents the mains, *b* the fuses, *c* the switch, *d* the distributing bus-bars, and *e* the branch circuits carrying lamps. Here a couple of feeders are taken direct from the service mains to the bus-bars of a distributing board, from which the lamps are served by four radiating branch circuits Only the feeders need be of sufficient size to carry the whole 12 amperes, and the branches may now consist of much smaller and less expensive cables. These also have the advantage of being more flexible, and are also more easily attached to the fittings. But the greatest advantage of the distribution-board system lies in the

extended scope it gives to the wiring; because working at the full current capacity of the cables, the branch circuits can be run to the full limit of volt drop on *each side* of the distributing centre, which practically doubles the area of supply, while still preserving the maximum current density in the cables.

Number of Lamps on one Branch.—The wiring rules recommended by the Institution of Electrical Engineers limit the possible number of lamp points on any single branch circuit to ten; and the current in such branches must not exceed 6 amperes on circuits up to 125 volts, or 3 amperes on circuits between 125 volts and 250 volts. This regulation should be noted carefully, because failure to comply with it may disqualify the wiring when being inspected by the company's inspector.

As far as possible, circuits should be so arranged as to equalise the number of lamps on individual branches, and they should not be loaded up to their extreme capacity at first, because it is often found a great convenience subsequently to add an extra lamp or other fitting not provided for at first.

Choice of Pressure.—While bearing in mind that the limitations imposed for branch circuit loads are either 3 amperes for a 200-volt supply, or 6 amperes for 100-volt systems, yet a choice of pressure is sometimes optional to the consumer, especially on alternating-current circuits. In such circumstances it is advisable for a beginner to select the lower voltage, preferably 100 or 110 volts, since insulation tests will give him less trouble, and an accidental shock or two, which he is almost sure to experience some time or another, will not render him so nervous. There is no necessity to transform down to 50 volts or even 25 volts, as was frequently done when metallic-filament lamps first came in.

Transformers.—On alternating circuits, the supply voltage, at whatever pressure it may be brought into the house, may be easily and conveniently adjusted to any desired extent by means of a step-down transformer. Wherever the pressure of the supply mains exceeds 100 or 110 volts alternating, it is recommended to reduce it by the above means, because this enables lamps to be used whose filaments are shorter and more robust, besides possessing a greater range of candle-power than the higher-voltage lamps have at present.

There are two kinds of transformers used in this connection, the "auto" transformer, and the "separate-winding" transformer. The former is slightly cheaper, but the latter is less likely to damage the lamps and fittings should any breakdown occur in its insulation. It is not necessary to enter deeply into technical particulars of their construction here; all that the wireman wants is a diagram of their windings and their connections to the circuit.

In Fig. 16 is given a diagram of the auto-transformer style of connections on an ordinary lighting circuit. *a* represents the service cables, *b* the service fuses, *c* the meter, *d* the switch, *e* the auto-transformer, *f* the secondary winding connected to house lamps *h*, and controlled by switch *g*. Here it will be noticed the primary or high-voltage connections are made between the extreme ends of the transformer windings, while the low-voltage house circuit is tapped off between one end of the primary winding and an intermediate point which is proportionate to the ratio between the two different pressures, the secondary part of the winding being of a heavier gauge, in order to carry the increased current consequent on reduced secondary pressure. Note, that one terminal of the transformer is common to both the high and the low voltage side. This is the one that must be connected to the "dead"

or "earthed" side of the service mains, when an earthed supply system is being dealt with.

When a double-wound transformer is installed, the connections will be according to the diagram presented by Fig. 17, where *a* represents the service cables, *b* the fuses, *c* the meter, *d* the switch, *e* the double-wound transformer with primary winding *f* connected to mains, and secondary winding *g* connected to house lamps, *h* the switch, and *k* the lamps. Both this and

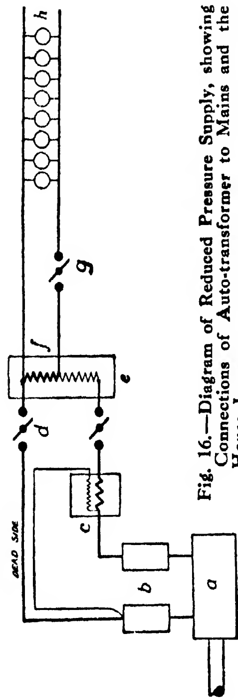


Fig. 16.—Diagram of Reduced Pressure Supply, showing Connections of Auto-transformer to Mains and the House Lamps.

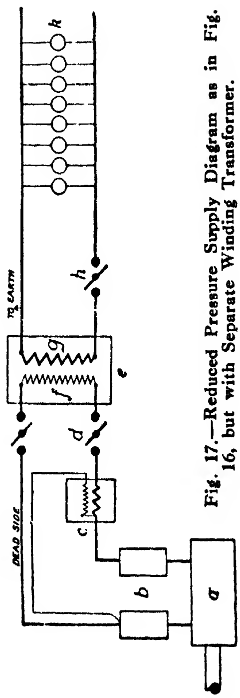


Fig. 17.—Reduced Pressure Supply Diagram as in Fig. 16, but with Separate Winding Transformer.

the preceding figure show how to connect on the supply meter, which is always placed in circuit between the company's service fuse and the consumer's main double-pole switch ; the transformer is the consumer's property, and has to be maintained at his expense.

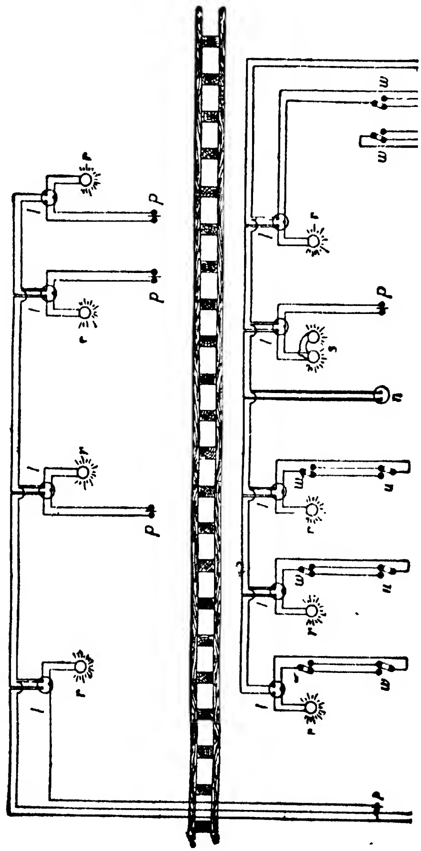
In a lay-out diagram, first proceed to indicate the run of the wiring, from the point where the company's cables first enter the building, to the distribution board. This portion of the circuit includes the consumer's main double-pole switch and fuses, and the meter ; but no other fittings of any kind, unless it is a transformer to reduce the house pressure, in which case its position is indicated in Figs. 16 and 17. It is the rule never to break the main circuit between the meter and the distributing centre, by including lamps or any fittings other than those necessary for protection of the circuit just mentioned, but to preserve the main cable run intact. Once the mains have reached the distribution board, however, they split up into branches, each one loaded with an approximately equal number of lamps.

There is no actual necessity to keep the load on each circuit exactly equal if it is at all inconvenient, and, generally speaking, it is usually found a more convenient plan to wire all the lamps on any one floor in a small dwelling-house on one particular branch of the distribution. Should any fault then occur it is comparatively easy to locate it. And if a branch fuse should happen to burn out, it does not extinguish the lights in several different parts of the house, but is confined to one floor only, and easily traced back to the fuseboard.

Schedule of Lamps and Fittings.—For the purposes of practical illustration, a typical double-fronted residence with cellars and three storeys will be selected as generally representing average lighting requirements.

Locality		*Lamp Points*	*Switch Points*	*Other Fittings*
Basement		—	D.P. main switch	D.P. main fuse Meter Transformer (if any)
Ground Floor	**Hall**	1/16 c.p. pendant	2/2-way switches	3-way distribution fuseboard
	Dining-room	1/2-light cluster 50 c.p.	1/ switch	—
	Drawing-room	1/3-light cluster 75 c.p.	2/ switches	1/16 c.p. standard lamp 1 wall plug
	Kitchen	1/16 c.p. pendant	1/ switch	—
	Scullery	1/10 c.p. bracket	1/ switch	—
First Floor	**Passage**	1/16 c.p. pendant	2/2-way switches 1/ switch	—
	Library	2/25 c.p. pendant lamps	1/ switch	1 table lamp 1 wall plug
	1st Bed-room	1/25 c.p. pendant	2/2-way switches	—
	2nd Bed-room	1/16 c.p. pendant	2/2-way switches	—
	3rd Bed-room	1/16 c.p. pendant	2/2-way switches	—
Second Floor	**Landing**	1/10 c.p. pendant	—	—
	Box-room	1/10 c.p. bracket	1/ switch	—
	Lavatory	1/10 c.p. bracket	1/ switch	—
	Bath-room	1/10 c.p. bracket	1/ switch	—

After going through the preliminaries already sketched out in previous chapters, it will be found to assist considerably if a schedule of all lights, fittings, etc., is drawn up, and tabulated in the manner shown on the preceding page.



Summarising the above, circuit No. 1 on the ground floor carries nine lamps; circuit No. 2 on first floor six lamps; and circuit No. 3 on second floor four lamps. Even with lamps of as high a candle-power

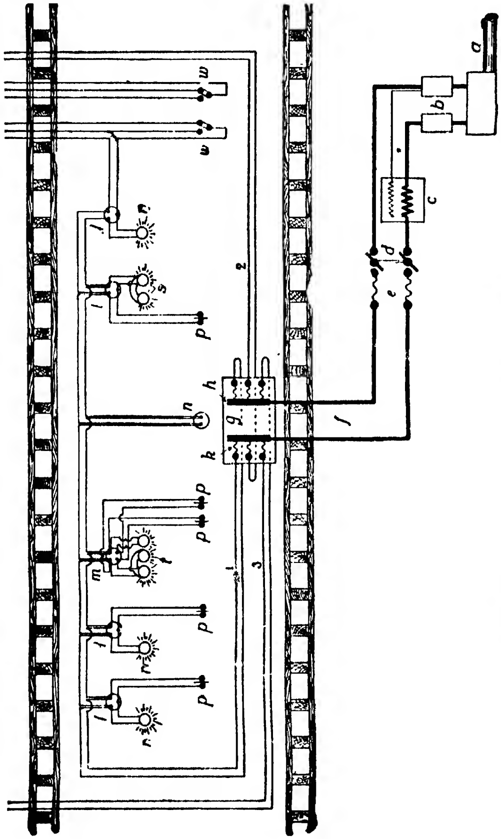


Fig. 18.—Wiring Diagram for Electric Lighting of Modern Three-storey Residence.

as 50 c.p. each, the most heavily loaded circuit (the ground floor) will only consume 4½ amperes on a 100-volt supply, or 2¼ amperes on 200 volts when all lamps are alight at once, which is therefore well within the limitations of the wiring rules mentioned previously, besides giving scope for a few additional lamps if required later.

Lay-out Diagrams.—Fig. 18 (pp. 44 and 45) is the lay-out for the above circuits, and will explain itself. All the lamps and fittings mentioned in the above schedule appear in this diagram, and are marked in the conventional manner: *a* represents the service cable, *b* the service fuses, *c* the meter, *d* the double-pole main switch, *e* the double-pole main fuse, *f* the feeders to distribution board, *g* the distributing fuse board with three circuits numbered 1, 2, 3, *h* the bus-bars, *k* the double-pole circuit fuses, *l* the 3-contact ceiling roses, *m* the 4-contact ditto, *n* the wall plugs, *p* the lamp switches, *r* the lamps, *s* the 2-light cluster, *t* the 3-light cluster, and *w* the 2-way lamp-switches.

CHAPTER VII

The Conduit System

THE object to be remembered when running the conduit for electric wiring, is to keep the runs as short as possible, and to use the fewest possible fittings necessary to serve the various lamp and switch points. An actual conduit diagram will frequently differ from a general lay-out scheme, because economies in material and labour can often be effected by such deviations. For instance, any single circuit rarely runs in regular order through all the rooms it serves one after the other, because the distributing centre is neither at one end nor the other of the run, but more often situated near the centre. Thus it is more convenient to supply a given branch with current by means of " rising mains " from the distribution board, which make a junction or T-joint with some point near the middle of such branch. In the conduit diagram presented by the frontispiece to this book, a special endeavour has been made to show this clearly by preparing the drawing in such a way that each room in the house appears in perspective with three out of four of its walls, also ceiling and floor, visible at once. The rooms being outlined in black, and all the conduits and electrical fittings being printed in red, makes it easy for the eye to trace out the run of the conduits, etc., without any confusion due to intermingling of the structural details of the building itself.

This frontispiece indicates the general run of the tubes through which the cables and wires are threaded or drawn, together with the various fittings used in conjunction. It must not be confused with a "wiring diagram," which is different altogether, as varying numbers of wires will pass through some of the conduits. This wiring is dealt with in a separate chapter, as it will be more convenient to take small sections of the wiring at a time, and show the various wires and connections on a somewhat larger scale for the sake of clearness.

Running the Conduit.—It may be explained that it is not necessary that every pair of wires should be run in its own conduit; for in certain circumstances it is advantageous to group several wires together and so save conduit and erection costs, even though occasionally the expense of a greater length of wire is involved.

Again, although electrically speaking, the shortest possible run from point to point is best, the nature of the buildings and damage to any existing decorations thereby entailed has also to be considered. In concealed work this is of secondary importance, and as a rule it is much cheaper and easier to wire a house in course of erection, than after the house has been built and furnished, because the runs may be made shorter and straighter, and there is a minimum of cutting-away and making-good to do.

Surface work, where the conduits are fixed on the walls, etc., in exposed positions, calls for some little care in selecting the most appropriate positions, so that it may be as inconspicuous as possible, while at the same time free from too many bends and special fittings. Angles between ceilings and walls, the tops of skirtings, under floor boards, etc., are usually the positions chosen for such work, and if the conduit is

painted the same colour as the other decorations it is seldom objectionable or too noticeable.

The worst possible position to run a conduit is across the middle of a ceiling or wall, because when a large plain surface is broken by anything in the nature of a pipe, the attention is sure to be arrested.

In the case of ceilings it is as easy to carry the pipe under the floorboards above, and drop a connection to the ceiling rose, as it is to resort to the aforesaid bad practice. Again, when necessary to serve a switch point by a surface conduit, it should rise from the floor, and not drop from the ceiling level.

The Coloured Conduit Diagram Explained.—A few words of explanation will be sufficient to guide the beginner in following up the coloured conduit diagram (*see* frontispiece).

The main service cables are indicated at their point of entrance into the building by service fuse boxes A and a meter B, which are the property of the supply company, fixed by them, and maintained in order at their own expense, except in regard to the fuses, which if necessary to renew by any act of the consumer, are generally charged to his account. From this point onwards, all the wiring and various fittings are at the expense of the consumer and must, as explained previously, be kept in fit and serviceable condition by him.

The main double-pole switch and fuse C is generally mounted on a small panel, with the fuses wired slightly "lighter" than those of the service boxes, so that in case of accident the consumer can renew his own fuses instead of having to wait the company's pleasure. From point C, the next step is unbroken until the main cables reach the distribution board D, unless a "transformed" supply is in vogue, when the consumers transformer would generally be placed in circuit im-

mediately above C. Leaving the board D will be noticed three vertical runs of conduit, which carry the "rising-mains" to each of the three floors, where they meet the branch runs by means of junction T-boxes, 1, 2, and 3, coloured full red in the diagram.

Various 3-way and 4-way boxes will be made use of for purposes of connecting up the interior wires conveniently, and their use and method of wiring will all be described in detail later. For the present it is sufficient to note that the plain switch points in the diagram are all lettered G, the 2-way switches H, and wall plugs K. Ordinary ceiling roses are indicated at E and brackets at F.

CHAPTER VIII

Erecting Conduit Throughout a House

THE coloured conduit diagram (*see* frontispiece) is self-explanatory in showing how to choose the shortest runs from point to point for the pipe work. Most of this will be concealed, being taken just under the floor-boarding for the horizontal runs, notching out the joists where necessary to sink the piping just below flush.

Many of the runs will travel with the joists, and in that case are supported by saddles or crampets, pipe-hooks, etc., as most convenient. But wherever it is necessary to raise boards for the purpose of running the piping, they should always be refixed with screws, and not nails. Vertical runs, down the walls to switch points, for instance, are sunk in a small chase cut in the plaster and afterwards cemented in. If from the nature of the decorations concealed runs are not possible, carry the conduit down an angle in preference to across a plain surface, and it is then hardly noticeable.

In some walls the plaster may be found too shallow to allow a round section of conduit to be sunk flush, in which case special oval conduits are procurable, and can be obtained with adapters enabling round-to-oval runs to be easily erected to accommodate such cases.

In sunk work but little fixing of the pipes is necessary, beyond the plaster and an occasional staple or two. On surface work use single pipe hooks where likely

to show, and saddles in the more inconspicuous positions. Special attention must be paid to firmly securing all wooden switch-blocks ceiling roses, brackets, plugs, etc., in fact all fittings subjected to any mechanical strain or weight, or they will work loose in course of time.

With the observance of these general recommendations, the erection of the pipe-work will present but little difficulty, especially if care is taken to avoid the inclusion of too many different boxes and pipe fittings and to keep to the same size of conduit throughout for the branch runs. Simplex conduit is made so exactly to gauge that there is very little trouble in fitting it together; and if the "screw-socket" type of junctions are used everywhere as recommended it greatly simplifies matters.

There is a fitting made for almost every conceivable requirement for turning angles, difficult jointing, etc., and the temptation is rather to multiply their number, unfortunately, instead of reducing and eliminating those little called for and standardising the really serviceable ones. The wireman must not be led into the error of elaborating too much, and should exclude from his supplies everything but just the plain normal bends, and the 1-, 2-, 3-, and 4-way junction boxes. With these there are very few buildings that cannot be satisfactorily wired, and there is no occasion to complicate matters by the addition of "special fittings."

The process of erection and wiring is extremely simple in the greater number of instances; it is only in connecting-up and in such technical matters as proportioning the size of cables, that ordinary common sense requires supplementing with extra guidance.

At the beginning of the work it is recommended to mark off the situations in the various rooms and passages selected for lamp and switch points, and to

fix the wood blocks to which these will subsequently be attached. A suitable location for the distribution and main double-pole switch and fuse needs to be chosen also, after which the wireman can proceed with his conduit runs from point to point. It will be best to take this work in sections, explaining at the time any difficulties that may be encountered.

Determining Size of Cables.—It is necessary first of all to decide on the size of cables, which determines also the size of the conduits. The house will be assumed wired up for three 3-ampere circuits from the distribution board outwards, and if these are fully loaded all at the same time, the main cables (those supplying the distribution board) must of course carry 9 amperes.

A seven-strand cable should be chosen for the mains $7/21\frac{1}{2}$ S.W.G. is a suitable size, its current-carrying capacity being $9\frac{1}{2}$ amperes. To accommodate the two cables easily, a $\frac{3}{4}$-in. conduit is necessary. The branch circuits can all be wired throughout with $\frac{1}{18}$ S.W.G. cable, which is the smallest wire permissible according to installation rules; this will carry 4·2 amperes as a maximum load. A $\frac{5}{8}$-in. conduit will carry four such cables, and although in most parts of the runs two cables only are needed, there are occasions when three and four cables are carried by one conduit, and the small saving effected by reducing the conduit diameter in places where it carries fewest conductors would be more than counterbalanced by the extra expense necessitated by increasing the sizes and numbers of fittings. The whole of the branch conduit runs will therefore consist of $\frac{5}{8}$-in. diameter tube, bends, and boxes.

From House Service Switch to Distribution Board.—Returning to the mains from the house-service switch to distribution board, the conduit diagram

shows the requirements to be four "normal" bends, that is easy right-angle bends as distinguished from sharp elbows, and a sufficient length of ¾-in. conduit to cover the distance between these two points. An enlarged diagram is presented by Fig. 19 showing this portion of the conduit, with the interior cables connected at the respective ends to the main switch and to the bus-bars of the distribution board. The wiring to the meter and the service fuses, below the consumer's main switch, had better be left for the supply company to attend to; but the consumer must find the necessary cable and other material. This, however, is done last of all, as the town mains will not be connected on until the inspector has passed the house-wiring as satisfactory.

Fig. 19 is a diagram of the wiring between consumer's main switch and distribution board. A is the main switch and fuse-board, recessed at the back for the entry of the conduit and connections to the fittings; *a* are the single pole switch terminals, and *b* the fuse terminals. B the distribution board with two bus-bars *g*, separated by a fibre partition; *h* the branch double-pole fuses, *k* the sweating sockets for the attachment of main cables; *c* the steel conduit in straight runs, and *d* the normal right-angle bends. The screw-socket clamps *e* are not drawn to scale, but show the positions they would occupy. The main cables *f* are shown by the heavy lines as though the conduit were cut in half to expose the interior, *l* are the wooden caps or bushes to prevent abrasion of the cables where they emerge from the metal pipes.

Erecting Conduit for Mains.—When erecting the conduit for the mains, the easiest method to follow will usually be to cut the lengths of straight pipe, fit the bends, and staple up lightly to the walls so that it can easily be taken down again. After thus ensuring that lengths are correct and that the screw-sockets

grip properly, it can be taken down, and the two main cables threaded through piece by piece. Then each length is put up again and stapled firmly to the walls.

Threading the Cables.—The two cables should be coloured one red and one black, and their ends are tightly twisted together for an inch or two, and turned back into a small eye so that the rounded end will not easily catch against any obstruction in the tubes. Do not attempt to thread through too long a length of

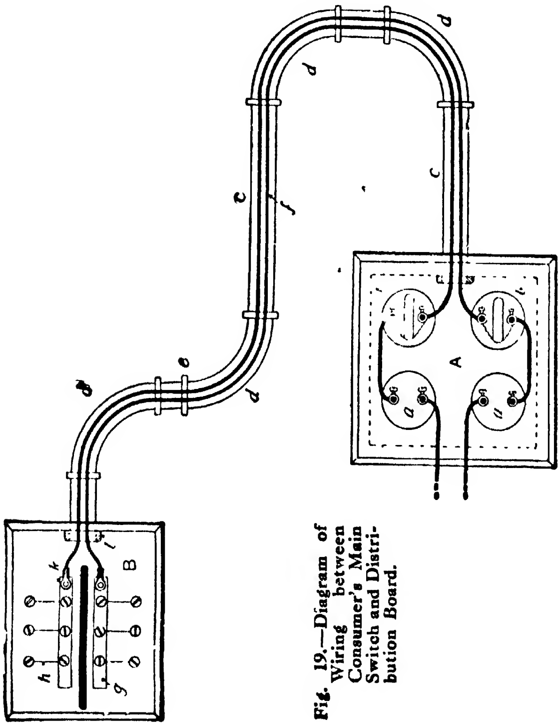


Fig. 19.—Diagram of Wiring between Consumer's Main Switch and Distribution Board.

conduit at once; but use a liberal application of French chalk to lubricate the cable and try to avoid any twisting of the wires.

Considerable care is necessary to avoid scraping the insulation when the cables are drawn across the edges of the metal pipes, and, to guard against this, procure a "bell-mouth" fitting, and insert in the end of every fresh length of tube, or every extra fitting temporarily while the pushing or drawing through process is in operation. Remove it, of course, when the next fitting is added, and so on. Where the steel conduit enters the side of the distribution board case, in fact, wherever the cables have to emerge from the unprotected ends of the metal pipe in order to enter a fitting of any kind, see that a wooden cap or "bushing" (supplied to suit all sizes of tubes) is inserted.

Fixing Main Switch and Fuse.—If the main switch fuse in the cellar is fixed to a brick wall or in a situation at all damp, it must be mounted quite clear of the walls, by being screwed or otherwise attached with four substantial porcelain bushes behind, clearing it from the wall by at least ¾ in. This switch-fuse fitting can be of the ordinary 10-ampere tumbler type switch and porcelain cutouts, the switches being linked together so that they operate on both poles at once.

Electrical Joints in Conduit.—One other precaution is necessary in fitting the conduit together. Conduits are enamelled inside and out with a special insulating enamel; but since wiring rules specify that the pipe work must be electrically continuous, it is necessary always to scrape or file off the enamel where the sockets occur, so that good contact may be made with the bare metal. These joints are afterwards touched up on the outside, where liable to rust, with similar enamel, or the whole pipework can be painted over to match the surrounding decorations.

Top Floor Branch Circuit.—Of the three branch circuits which issue from the distribution board shown in the conduit diagram, the one which serves the top floor will be the easiest to deal with, as the fittings are simple, and there are no complications in the way of two-point switch control to any of the lamps.

The structural arrangements of different houses, of course, vary in detail vastly; but all circuits can be resolved more or less into the general lines laid down in the lay-out diagram (Fig. 18, pp. 44–45), and such deviations as would occur in the way of additional rooms, front or back, are met by an extra junction-box serving the back rooms or by simply extending the run in the case of front rooms. There may be more angles and turns encountered also than in the typical case illustrated; but with the examples and treatment of circuits here shown, the wireman should not experience any great difficulty in adapting his conduit runs to the exigencies of the case and the contours of the rooms.

In Fig. 20 is figured circuit marked No. 3 in the general diagram of wiring above referred to, the conduit and fittings being drawn in part section as before in order that the wiring connections may be plainly traced out. The first part of the conduit to erect is the rising main A, which runs straight up to the rafters above the top ceiling and into a T-connection box with three outlets B. This is a useful fitting in such cases, as it enables good joints to be secured without the use of solder, or of re-insulating the cables. In the interior of the box will be seen a porcelain fitting, C, which carries two metal straps D separated by a bridge of porcelain between them. This fitting not only serves as a junction or through connection between cables on the same run, but also as a T-connection from the rising pair of cables to the horizontal pair as shown, the

wires being securely clamped under the screw heads, and the one that passes to the upper run taken through the hole in the porcelain " bridge " to keep it out of contact with its neighbours.

It should be remembered that only just sufficient insulation should be removed from the wires to enable the bare end to encircle the screw for attachment ; and, although apparently a trivial matter, it is not out of place to mention, too, that there is a right and a wrong way of fastening these ends. The proper method is to turn the wire loop round the screw shank in a clockwise direction, so that tightening up the screw draws the wire, if anything, up into a still smaller loop. If attached with the reverse turn to the loop, there is a decided tendency for the wire to spread, and bad contact results.

To the left of the junction-box a pair of wires serves the single lamp in the bedroom, which is a bracket fitting E, secured to a simplex 2-way box, one wire taking in the switch F on the way.

On the right of the junction box the first lamp encountered is a pendant G, and here the conduit runs into a simple 3-way box H, enabling the wires to be " looped " out as shown into the 3-plate ceiling rose I below, without cutting them. The lamp itself is suspended by ordinary twin flexible 35–40 wire from two of the plates in the rose, and another pair of switch wires runs back and into the same 3-way box again for continuation to the point J, from which it is desired to control this lamp, and thence to the switch K on the landing or stairs below. It will be necessary at J to provide a box with four outlets as shown, as besides continuing the branch mains to serve the remaining lights in storeroom and bathroom respectively, it will be a convenient point to wire, the switch run, L, from which controls the storeroom lamp M. One side of the branch main is, therefore, looped down to this switch,

and then continued straight to one terminal of the switch N in the bathroom, which, note, should be out of reach of the occupant of the bath, to avoid possibility of dangerous shocks. The other side of the branch

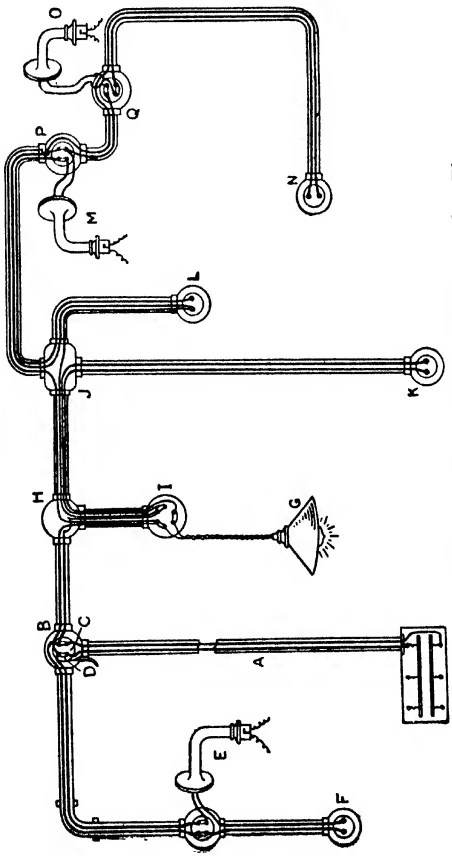


Fig. 20.—Detailed Wiring Diagram of Top Floor.

main serves one terminal of each of the two lamp brackets, M and O, while the respective switch wires back to the other lamp terminals complete the circuit.

This circuit from the distribution board therefore calls for the following fittings:—Sufficient $\frac{5}{8}$-in. conduit with screw-socket junctions for the straight runs; one T-junction-box B; one 3-way ordinary box H, one 4-way ditto, J; three 2-way ditto for lampbracket attachment, E, P, and Q; and four one-way or terminal boxes for switches F, K, L, and N. The switches are of the ordinary 5-ampere tumbler type, the ceiling rose I of china with 3-plate interior, and the lampbracket fittings E, M and O, 2-way boxes, with 2-plate porcelain interiors in order that the service cables do not need looping in to the lampholder terminals, as neither tube nor terminals are large enough to contain the wires. It is, therefore, recommended to wire the brackets and lampholders with a piece of twin flexible first before fixing them, and then attach the ends to the respective contact plates in the 2-way bracket boxes all as shown in the diagram. Enough "normal bends" will have to be provided, of course, to negotiate the various angles; but the fewer the better, straight runs being the object wherever possible. Simplex fittings in the way of switches, ceiling roses, brackets, etc., are all obtainable specially adapted for fixing to and use with Simplex tubing and boxes, and they certainly make a better mechanical job, than by adapting the ordinary commercial porcelain fittings, which are largely the relics of the old wood-casing days. The various types of circular porcelain interiors sold to fit the standard 1-, 2-, and 3-way boxes, enable almost any kind of junction to be neatly carried out, whether "through," "T-," or "mixed," and it is much better to preserve the system in its entirety by using the fittings designed consistently with the object in view.

Erection of the conduit is best carried out by first cutting to length and fitting all tube and bends, boxes, etc., lightly fixing them in position so that they can be taken down and the cables threaded through. In certain cases where the tube is embedded in the walls, as, for instance, most switch runs, drawing in is resorted to, a steel tape being pushed through from the nearest junction or inspection-box and the cables attached to its end and hauled through, by the aid of a liberal lubrication in the form of French chalk blown into the tube previously.

The top-floor combined conduit-wiring diagram already given is a comparatively simple circuit without any complications in the switching arrangements; and the wireman, having familiarised himself somewhat with the grouping of the wires and arrangement of junction and outlet boxes there shown, will now more readily be able to understand the diagrams about to be presented.

The remaining two circuits from distribution board to first floor (Fig. 21) and to ground floor (Fig. 22) respectively, will be dealt with, and as a portion of the wiring as regards the hall lamps runs from one floor to the other, it will be best to show the two circuits on opposite pages (see pp. 62 and 63) in order to show the switch and lamp points more or less in their actual relative positions.

First Floor and Ground Floor Circuits.—The first-floor circuit, as shown in Fig. 21, is served by a rising main from the middle pair of fuses on the distribution board, while the ground floor is served from another rising main coming away from the extreme left-hand pair of fuses. Only one circuit is shown at a time on the distribution fuseboard, to avoid complicating further what is already rather an intricate diagram.

As with the first circuit, an endeavour has been made to simplify matters so far as possible, consistent

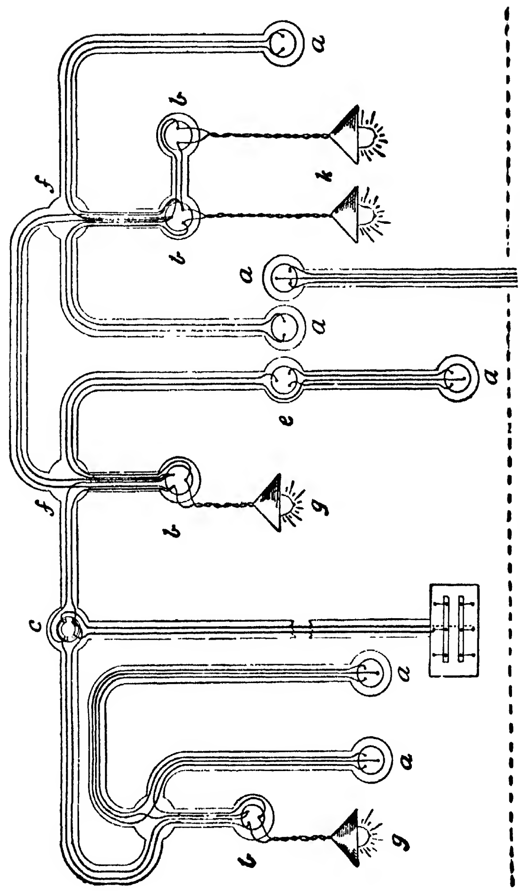


Fig. 21.—Circuit from Distribution Board to First Floor.

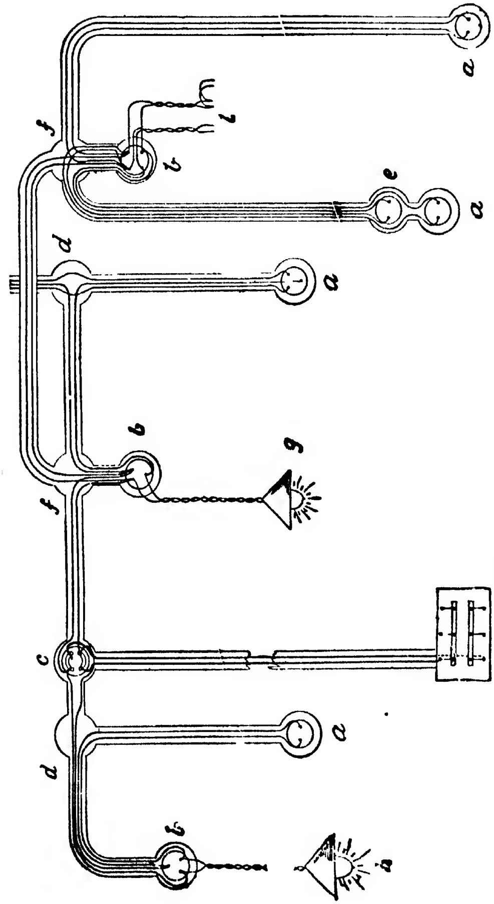


Fig. 22.—Circuit to Ground Floor.

with good work, by reducing the number of conduit fittings, and employing, besides the usual plain tube and normal bends, only the circular type of boxes with varying numbers of " ways " required to lead the wires in the directions necessary. For instance, terminal or one-way boxes are used at all switch points, where the tubing which leads the wires to the switches terminates (see *a* in both figures). It might also prove convenient to use the same kind of boxes for lamp points where the wires serve a rose attached to the ceiling, as at *b*.

The usual practice, however, in such cases is to employ a box with two outlets at right angles to one another, and fix it to the side of a rafter, or a joist under the floor with the tube carrying the wires running into it horizontally, and emerging vertically downwards to the ceiling rose beneath, the intervening space, if any, being protected by a short length of steel tubing. Do not omit this precaution, however tempting it may be to do so. Rats have been known to gnaw through the coverings on a few inches of exposed wiring under the floorboards, with disastrous results both to themselves and to the premises. Shavings are often allowed to accumulate among the joists when the floors are laid, or the conduits being fixed, and are easily kindled by the flash from a momentary short-circuit before the circuit fuse blows. And not only is fire risk present in such circumstances, but the insulation resistance of the whole wiring may deteriorate appreciably in course of time if this precaution is neglected.

Both the rising mains which serve the two floors are first taken to 3-way T-junction boxes *c*, which have porcelain interiors fitted with brass blocks and connecting screws. By this means connection is made to the horizontal run of wiring on both sides, and soldered joints avoided.

A noticeable feature of this installation is that the "looping-in" system is adopted throughout. Although this leads to an inevitable congestion of wires in a few portions of the tubing, it is far better practice than that of cutting, jointing, and more or less imperfectly re-insulating such joints at frequent intervals. Moreover, as the wiring is all threaded through the pipes, as they are erected, and not drawn in (as previously described), the conduits can be filled to their full capacity without risk of damage to the insulation. If the circuit wires be carefully tracked through in the diagrams, from the point where they connect on to the T-boxes *c*, it will be seen that each wire serves in turn one point of every lamp-fitting *b*, then loops back again into the box it started from, to continue its unbroken course to the next point.

Besides the 1-way and 2-way right-angle boxes above mentioned, a few 3-way or T-boxes will be needed, two for the junctions at *c*, and two others without the porcelain interior at *d*; their purpose is obvious without further remark. At *e* two more 2-way boxes are necessary; but this time they will be more convenient with the outlets running straight through instead of at right angles to one another. And finally, there will be needed five 4-way boxes, to occupy the positions shown at *f*.

The circuit on the top floor contained only lamps controlled from one point. In the present diagram, however, there is only one lamp having simple 1-point control, namely, that on the ground floor, marked *h*. At *g* will be seen lamps it is now requisite to operate from two different points, and special 2-way switches are here needed, which enable the lamp to be turned on or off from either of the two switches forming a pair, irrespective of the position of the other switch. Such switches are similar to ordinary 1-way tumbler switches

in appearance, but have two pairs of contacts inside with one side of each linked together, so that current can be deflected from the linked side to either of the other two insulated contacts, by the movement of the switch-lever. The landing and the bedroom lights are the ones which require to be worked on 2-point control.

On the first floor, on the right of Fig. 21 (corresponding to the library), two lamps, *k*, will be seen connected in parallel, both these being under the control of one switch on the left. The fitting at *a* on the extreme right is a 1-way or terminal box containing the socket for a wall plug, for use with a table or portable standard lamp. The same description applies to the right-hand fitting in a corresponding position on the ground floor. (Fig. 22.)

In the drawing-room a three-light fitting *h* is shown controlled by two switches on the left at *e* and *a*. Switch *e* controls one lamp, and switch *a* two lamps, thus either one, two, or three lights may be switched on at will.

Any extensions required to the number of lamp points or switches shown in these diagrams can be added in the same manner, the wiring instead of terminating at a lamp or switch, being simply looped back and continued forward as required. Care is necessary, however, not to exceed the permissible load in lamps on any one circuit, this being, as previously noted, three amperes on a 200-volt supply, or 5 amperes on a 100-volt supply, for any one circuit running out from the distribution board.

Erecting the conduit and running the wires is carried out just as with the top floor, first cutting the tube to length, fixing temporarily the boxes, etc., in position, and afterwards taking everything down piece by piece, and threading the wires through. Use plenty of French

chalk during this process, and take care no insulation gets scraped by chafing on the sharp edges of the tube while being pushed or drawn in. Once the wires are in place, fix the conduit firmly with staples or crampets. Needless to say, conduit erection is not a one-man job, and calls for an assistant. Ceiling roses, switch blocks, etc., can all be fixed and the wires brought through; but the actual fittings themselves should never be put up until all other work is finished.

A reminder may again be given to scrape or file off the insulating enamel with which the conduits are coated wherever a socket junction occurs, because, in order to conform with wiring rules, the tubing itself must preserve its electrical continuity throughout from one end to the other.

An equally important point is to ensure that the tubing is efficiently earthed at two places, and preferably three; one at each end of the tubing and another in the centre. This is easily accomplished by using Simplex earthing-clips which are cramped on the pipe (previously scraped bright), and attached by a good stout copper wire to the nearest convenient water pipe. Earthing to gas-pipes is not permissible. All couplings and joints where the original enamel has been damaged should be repainted with a similar substance to prevent corrosion; and if the pipes are exposed they can be painted or otherwise coloured to harmonise with adjacent decorations.

Finally, remember that any difficult corners to negotiate or special fittings required to accommodate an unusual case can generally be procured from the makers of Simplex fittings. Such articles as round-to-oval adapters, enabling an oval tube carrying wires from ceiling down a wall to a switch point, for instance, will sometimes be found exceedingly useful where the plaster is too shallow to otherwise sink the pipe below the

surface, and often prevents an unsightly appearance. A great number of special fittings other than those described here are obtainable; but their introduction has been purposely avoided, because in the most part they find their application only in the skilled wireman's hands, and simplicity, not elaboration, has been the object throughout the chapters of this book.

CHAPTER IX

Testing a Wiring Installation

THE test of an electric light wiring installation is essential, and consists in taking the insulation resistance of the wiring, and proving the continuity both of the various circuits and the metallic tubing as a whole in which the wires and cables have been run. Sometimes the first results are somewhat discouraging, owing to inexperience or to some mishap to the insulation when drawing the wires through the tubes; but particular emphasis must again be laid upon the necessity for obtaining absolutely satisfactory insulation before inviting the supply company to connect up to their mains, for they will most assuredly refuse to do so unless the insulation test is up to the standard of their requirements.

The instruments required in taking the tests are three cells such as used for bell work, either of the wet or dry type, giving about 4 volts; an ordinary electric trembling bell; a few short lengths of bell wire or electric branch cable for connections; and an ohmmeter and generator. The first three items are easily acquired, and the latter is always to be hired from any electrical house for a small fee, as it is too expensive an instrument to be worth while purchasing for a single job. If possible, it is more convenient to hire the form known as the "megger," which combines both generator and ohmmeter in one, and is, consequently, simpler

to connect up. The bell and batteries are required for the "continuity" tests, and the megger for the resistance test.

The Ohmmeter.—The construction of the ohmmeter will be better understood from Fig. 23. This shows the essential working parts of the instrument; but not the exact relative position of its parts internally. It consists of two coils G and H, whose axes are at right angles to one another, and the magnetic needle F pivoted in the centre of both coils is, therefore, under the influence of whichever coil gives the most powerful magnetising effect. A pointer K attached to this needle indicates its

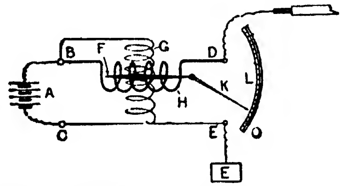


Fig. 23.—Diagram of Ohmmeter Connection.

deflections on a scale L marked in megohm values (the megohm represents one million ohms), and varies between O and infinity. The terminals B, C, D, and E are for attachment to the outside wires, etc., B and C being connected to the generator A, which is self contained in the megger, or to a separate hand-driven magneto dynamo capable of generating a pressure about double that of the circuit supply. The coil G, it is evident, is connected as a shunt across these terminals, and, consequently, when no cables are connected to D and E, or the resistance of any such cables is extremely high, practically all the current generated by A passes through G, and deflects the needle and pointer to the "infinity" end of the scale. When a cable having an inferior insulation value such as M is connected on, a certain proportion

of current generated in A leaks through its coverings to "earth," and finds a return circuit through the corresponding earthed terminal E of the ohmmeter. All current passing by this route through coil H tends to deflect the needle and pointer towards the O end of the scale, and so according to the balance between leakage current through H on the one hand and non-leakage current through G on the other, so is the final position of the

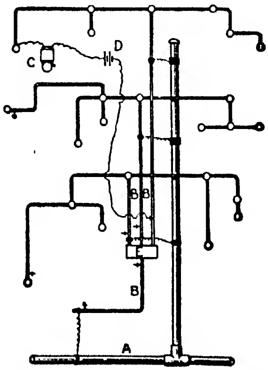


Fig. 24.—Testing for Continuity of Conduit, and showing how Conduits are Earthed.

pointer on scale L determined. The scale is calibrated to read in megohms, and unless a controlling magnet is employed to bring K to zero, irrespective of its position in the magnetic meridian, the instruments need setting by hand and levelling until this condition is obtained before putting in use. Instructions, however, will generally be found affixed to the inside of the case.

Continuity Tests.—The first and simplest tests to carry out are those relating to continuity. It is best to begin by testing the steel conduit system itself in which the cables have been run, as this test is quite easy to

carry out. Although there appears to be no hard and fast rule laid down by supply companies in Great Britain as to permissible resistance allowable in the steel conduits themselves, and no proviso except that such shall be "electrically continuous," yet some fire offices stipulate that the conductivity of the pipe-work as a whole must be such that it is possible to ring an electric bell from a 2-volt battery, using the extreme length of tubing as one conductor and a copper wire for the return. The idea is exemplified in Fig. 24. The bell C connected to the battery D should ring on connecting it between extreme lengths of tubing on each individual circuit B. Suggested points for attachment of wires are shown by the various arrows. The pipe-work here is imaginary, and must not be taken as exactly representing the conduit diagrams that have been given previously. Incidentally, Fig. 24 also shows how the conduit runs should be earthed, by means of the special earthing clamps procurable for that purpose. These are connected with the nearest water-pipe (*not* gas pipe) by a good stout copper wire, say No. 14 S.W.G.

It is not usual to earth more than one point on the pipe-work; but this practice is to be deprecated, if for no other reason than that the presence of a wooden distribution board, as at E, is sure to break the electrical continuity between various branches and the mains. But it may be more convenient to earth all the branches at their lower end instead of on each floor, as shown, especially where the water-supply pipes A are not carried upstairs.

Should any break be found in the electrical connection of the piping, the various lengths of straight tube, bends, and various fittings must be explored one by one, beginning at the point nearest to the copper-wire attachment from the bell, until the faulty joint has been found and remedied.

The next thing is to test for electrical continuity of the wiring itself, and, although often regarded as a somewhat superfluous operation, it should not be omitted. To carry out this test, attach the battery terminals to the extreme ends of the main cable, where they will presently be connected on to the supply company's service, and making sure that the fuses have all been inserted in the distribution board (and elsewhere if any exist), and that all switch points are closed, it should

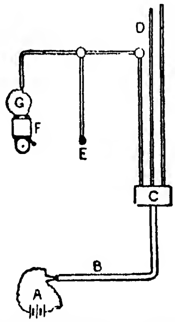


Fig. 25.—Testing for Electrical Continuity of Cables.

be found possible to get the bell to ring from any one of the lamp points. A "lamp point," it must be remembered, is considered as any part of the wiring from which it is proposed to take current for lighting or for heating, such as the two plungers in every lamp-socket, or the holes in a wall plug fitting; Fig. 25 will explain without further description the above operation. A portion only of the circuit is shown, sufficing to indicate the test to be applied to each point. The battery A is connected to the main cables B at the end farthest from the distribution board C, from which the various runs D emerge. One of these is shown with one lamp

point G and one switch point E. If the latter is closed and the fuses placed in position at C, the bell F should ring if the wiring is intact.

Taking the Insulation Resistance.—Provided continuity is found perfect everywhere, the next and most important test may be proceeded with, namely, taking the insulation resistance. There are two separate tests required for this, one of which accounts for the insulation of the wiring and fittings as a whole from earth, and the other is required between the positive and negative sides alone without reference to earth.

The former test is carried out thus: Join the ends of the two main cables together temporarily, at a point nearest the service connection, baring the copper for this purpose and twisting together for an inch or so. See that every switch in the building is " on," and every fitting, lamp, and portable apparatus connected up, as well as all fuses in. Then connect the main cables by a copper wire to the ohmmeter terminal marked " line " (and see that this connecting wire comes into contact with nothing else, nor with the ground or walls of the building), and the ohmmeter terminal marked " earth " to the most convenient neighbouring water pipe. Turn the handle of the generator at the prescribed rate of speed (according to instructions furnished with the instrument), and the pointer will travel over the scale and come to rest opposite a division representing the resistance of the whole installation in megohms. The nearer to the " infinity " mark the pointer stands the better, and more perfect will be the insulation. If, on the other hand, the pointer swings to or near zero, it indicates considerable leakage of current to earth, and may frequently be traced to a loose strand of flexible wire in some of the fittings, making contact with the surrounding earthed pipe. Whatever the cause may be, if the insulation tests out low, it must be put right,

and the best way to localise the fault is to get an assistant to switch off, first, the various branch circuits at the distribution board, until the faulty one is discovered, and then, with this circuit in and the others out, proceed to switch off lamp after lamp, beginning at the farthest point until, as will most likely be the case, on turning off one particular lamp, the insulation resistance suddenly jumps up to a high value, indicating that the defect has been located.

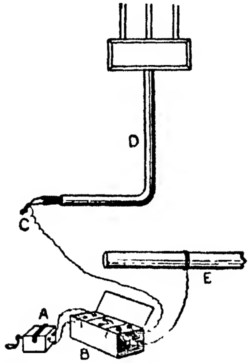


Fig. 26.—Testing Insulation Resistance of the whole of the Wiring.

The testing arrangements for this process are shown by Fig. 26, where the generator is shown separately at A and connected to the "generator" terminals of the ohmmeter B. The bared ends of the main cables C are attached to the "line" terminal of B, and the remaining "earth" terminal connected with a water pipe E. The wire from C to B must be carefully kept from touching anything else, but the terminal and the test cables. D represents a portion of the conduit as far as the distribution board.

"Pole to Pole" Test.—One more test will now suffice, provided all else has proved satisfactory, and that is the "pole to pole" test. This necessitates separating the wires at C (Fig. 27), and reconnecting "line" and "earth" terminals of the ohmmeter to the two bared cable ends. The connection to earth is not needed now, it being the aim to ascertain that the outgoing cable is well and efficiently insulated from its neighbouring return cables throughout the system. All

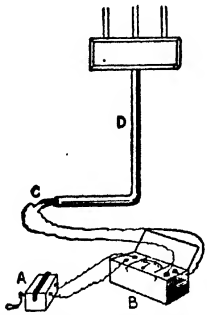


Fig. 27.—Testing Insulation Resistance between Lead and Return Conductors.

switches and fuses must be left in; but every lamp taken out of its socket, heaters disconnected, etc., in fact, all lamp points left open. There is little likelihood of any fault showing up on this test, except it may be due to imperfect wiring in the fittings, particularly such things as loose strands of flexible in lampholders or ceiling roses. It must be remembered, however, that all tests except continuity tests will give various results according to atmospheric conditions, the natural dryness or otherwise of the situation, and state of the building whether freshly erected or otherwise. It is as well, therefore, when possible, to test on at least two

different occasions, when the extremes of the above conditions prevail.

Final Test.—The standard of insulation to which the wiring as a whole must conform, varies somewhat according to the rules of the particular supply company or insurance office interested in the building; but as a general thing the recommendations of the Institution of Electrical Engineers as set forth in their 1911 Wiring Rules will be accepted as satisfactory. These stipulate that current shall not be switched on until the following test has been applied to the finished work: The whole of the lamps having been connected to the conductors, and all switches and fuses being on, a pressure equal to twice the working pressure must be applied, and the insulation resistance of the whole or any part of the installation must not be less in megohms than 25 divided by the number of lamps. When all lamps and appliances have been removed from the circuit, the insulation resistance between conductors must not be less than 25 megohms divided by the number of lamps. The insulation of any individual sub-circuit must not fall below 1 megohm. Any motor, heater, arc lamp, or other appliance may be connected to the supply of electrical energy, provided that the insulation of the parts carrying the current measured as above is greater than 1 megohm from the frame or case.

CHAPTER X

Wiring Rules and Regulations

It is proposed to devote this short chapter to the more important rules which have been drawn up by various authorities for the guidance of wiremen and contractors.

In the earlier days of electric lighting practice varied considerably, not only in methods of running and protecting the circuits, but also in permissible size of the conductors themselves. Experience showed, in course of time, that some of the regulations then enforced by fire insurance offices were of needless stringency, while others were too lax. Often, too, these rules were framed by advisers who were not electricians. In the natural process of time, experience has shown what to discard or modify and what may be retained, and a considerable degree of uniformity has now, happily, been arrived at in the production of wiring regulations which shall give all possible scope to the development of electric supply, and at the same time afford the necessary protection to life and property.

The following extracts represent the accumulated experience of electrical contractors, fire offices, cable makers and municipal associations throughout the country, and have been drawn up and formally issued by the Wiring Rules Committee of the Institution of Electrical Engineers. Only those of principal importance need be mentioned here, and anyone wishing to study them in full can obtain a copy for a few pence

on application to the Secretary of the above institution at Victoria Embankment, London, W.C.

At the outset it must be understood that the following extracts apply to low-pressure systems, that is not exceeding 250 volts. Medium and high pressures ranging from 250 volts to 650 volts and over come under special Home Office regulations, but as such pressures are very rarely brought into any private dwelling-house they will not be considered here.

1. In all cases before beginning to wire an installation, notice should be given to the local supply company, and to the fire office interested.

2. Every wiring system (except earthed concentric) must be protected by linked double-pole switches and fuses placed as near the entrance of the cables in the house as possible.

3. Distributing centres should be fixed from which branches radiate to the various lamps. No such branch may carry more than 6 amperes on circuits up to 125 volts, or 3 amperes between 125 volts and 250 volts, and the maximum number of lamp points per branch ought not to exceed ten. Heater circuits and feeder circuits to sub-branch distribution boards come under special regulations as regards current.

4. Every branch circuit must have a double-pole fuse.

5. If the supply is alternating current, lead and return currents on the same circuit must be bunched together if steel conduit is used.

6. No contact must exist between conduits and conductors, or earth wires and gas-pipes.

7. Earthing conductors must be proportioned of at least one 14 S.W.G. copper wire for every 50 amperes or less of current in the system.

8. In bathrooms and damp places precautions are necessary to avoid personal contact with any fittings likely to become "live."

9. No conductor (except flexibles) must have a sectional area less than the equivalent of 18 S.W.G.

10. The size of cables must be proportioned so that the drop in pressure at the farthest lamp does not exceed 2 per cent. plus 1 volt.

11. Conductors used in steel conduits should be taped and braided.

12. Flexibles employed for pendant lamps, etc., must have a sectional area not less than the equivalent of No. 22 S.W.G.

13. All metal conduit systems must be electrically continuous throughout. Conductors require to be mechanically protected up to the fitting itself.

14. All joints in wires are a source of weakness, and should be avoided wherever possible.

15. All switches and fuses must be of fireproof, incombustible, and moisture-proof material. Fuse wires on circuits carrying less than 10 amperes should be proportioned to interrupt the current when it rises to three times the working value. No fuse smaller than 3 ampere to be inserted in any circuit; fuses should not be placed in lampholders, plugs, or ceiling roses.

16. Ceiling-rose bases and covers must be of non-combustible and non-metallic material. The terminals should be arranged so as to relieve the direct pull of the fitting and card on its terminals.

17. Combined gas and electric fittings are not permitted, and if existing gas fittings are used they must be entirely disconnected from the gas supply.

18. Incandescent lamps must not be placed close to combustible materials unless specially protected. Cord grips should always be used in the lampholders.

The following abridged table of copper wires and cables will be found useful when laying out the wiring diagrams, particularly column 4, which shows the extreme length of circuit permissible when full load of

current is passing to comply with Rule 10 given above. For instance, the limit of volt drop on a 200-volt circuit is 2 per cent. plus 1 volt, or 5 volts total. Thus, using a $\frac{1}{18}$ conductor loaded to 7.2 amperes, there is 1 volt drop for every 10 yards of lead-and-return circuit. Therefore, the maximum length of wiring permissible on that particular circuit would be 50 yd. If a longer circuit were found necessary, a larger conductor would have to be chosen, and not loaded up to its full capacity.

TABLE OF ELECTRIC-LIGHT WIRES AND CABLES

Number of wires and gauge in S.W.G.	*Sectional area in square inches*	*Maximum permissible current in amperes*	*Total length in yards of lead and return giving 1 volt drop*	*Minimum insulation resistance in megohms for cables up to 250 volts*	*Resistance in ohms per 1,000 yds.*
3/25	·0009	3·7	10	1,250	26·01
3/24	·0011	4·5	10	[illegible]50	21·50
3/23	·0013	5·3	10	1,250	18·07
1/18	·0018	7·2	10	2,000	13·29
3/22	·0018	7·2	10	1,250	13·27
7/25	·0022	8·6	10	1,250	11·12
3/21	·0024	9·5	10	1,250	10·16
1/17	·0025	9·8	10	2,000	9·761
7/24	·0026	10·4	10	1,250	9·19
3/20	·0030	12·0	10	1,250	8·0
7/23	·0031	12·4	10	1,250	7·72
1/16	·0032	12·9	10	2,000	7·47
3/19	·0037	14·8	10	1,250	6·504
1/15	·0041	16·3	10	1,250	5·905
7/22	·0042	17·0	10	1,250	5·672

TABLE OF ELECTRIC-LIGHT WIRES AND CABLES (*continued*)

Number of wires and gauge in S.W.G.	*Sectional area in square inches*	*Maximum permissible current in amperes*	*Total length in yards of lead and return giving 1 volt drop*	*Maximum insulation resistance in megohms for cables up to 250 volts*	*Resistance in ohms per 1,000 yds.*
1/14	·0050	19·0	10	1,250	4·783
3/18	·0053	20·0	11	1,250	4·516
2/21	·0055	21·0	11	1,250	4·343
7/20	·0070	24	12	900	3·431
7/19	·0086	28	12	900	2·779
7/18	·0125	34	14	900	1·930
7/17	·017	40	17	900	1·418
19/20	·019	43	18	750	1·266
7/16	·022	46	19	900	1·086
19/19	·023	47	19	750	1·026
7/15	·028	53	21	750	0·8578
19/18	·034	59	23	750	0·7125
7/14	·035	60	23	750	0·6949
19/17	·046	70	26	750	0·5234
19/16	·060	83	29	750	0·4007
19/14	·094	113	33	600	·2565
37/16	·117	130	36	600	·2059
37/14	·182	172	42	600	·1318

The above table should be read in conjunction with Rule 10, remembering that it is not only the current that determines the choice of a cable, but also the volt drop governed by the length of circuit.

CHAPTER XI

Jointing Electric-Light Wires

HAVING now described house wiring, and before dealing with private lighting plants in which the motive power and generating apparatus is all contained on the consumer's own premises, it may be appropriate to give a few hints and instructions relative to the jointing or splicing of electric wires and cables. In this regard one has to remember that the best practice is to have no joints whatever in an installation when it can be avoided; joints are always a source of unreliability, more particularly as regards their subsequent insulation.

Owing to the prevalency of the looping-in system previously described, jointing in branch circuit wiring has almost disappeared from modern practice, although looping-in can be and frequently is carried to a rather ridiculous extent. Cases sometimes occur where the saving in length of cable and reduction of volt drop thoroughly justify a well-made joint in preference to looping. However, in the ordinary way, branch circuit jointing is the exception, and it is usually mains, sub-mains, and feeder circuits that occasionally require splicing or taping.

Joints all come under one of two headings; either the wires are spliced together, soldered, and re-insulated, or the ends of the cables are bared and mechanically secured together with pinching screws, clamps, or connectors. The latter type of joint can be protected

by porcelain insulators or junction boxes, but it should never be taped like a soldered joint, as it may require to be inspected and cleaned from time to time. The better practice is, of course, to solder a joint and re-insulate it with tape, as such junctions are both mechanically and electrically good, and when made by an experienced workman seldom give rise to insulation troubles.

The methods employed in jointing depend largely on the nature of the coverings used on the cables, whether gutta-percha-, rubber-, paper-, or lead-sheathed. Special systems of jointing boxes have been prepared by various makers to suit different systems of concentric and special

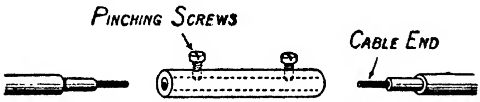


Fig. 28.—Plain Brass Connector.

wiring, but only the jointing methods applied to ordinary rubber-covered wires and cables need be considered here.

All electrical wires are either solid or stranded. Small current branch circuits are frequently wired with single strand 18 or 16 S.W.G., but for heavy current work multiple strand cable must be used. Stranded cables usually are made up of 3, 7, 19, or 37 single wires, these being the multiples that form up into approximately a circular section, and naturally those with the fewest strands are the easiest to joint. Single strand jointing will therefore come before us for the first consideration.

The easiest kind of joint to make in single-strand wire is accomplished by a simple brass connector (Fig. 28) with two pinching screws. The bared ends of the copper cables are pushed half-way into the interior

and secured by the screws. This is only practicable in situations where the connector-joint can be fixed clear of the walls or conduit, as, of course, there is no attempt at insulation. A better arrangement is shown

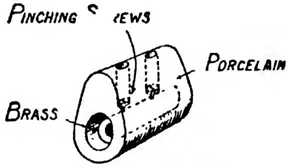


Fig. 29.—Porcelain-sheathed Connector.

in Fig. 29; here the connector body is sunk entirely in an outer porcelain sheathing, which protects all metal parts from exterior contact. In stripping the cables for this kind of joint only just sufficient of the covering must be removed for the purpose of contact with the pinch screws, and no bare copper should show outside the barrel of the connector.

Passing from connector-made joints to spliced and soldered joints, these are usually of two kinds, "straight-through," and "T-joints." Either kind is quite simple to make, the chief precautions necessary being to avoid "nicking" the wire when peeling off the outer insulating covering, as this may lead to breakage at this

Fig. 30.—Ordinary Twisted Joint.

point. Also, the wires must be perfectly clean and bright, or they will not take the solder properly. A good flux is essential, and no acid must be used on any account, or corrosion is certain to occur, even under the insulating tape. Resin is unsatisfactory, but any of the advertised resinous pastes can be used.

provided the joint is well washed before the tape is put on. Fig. 30 illustrates the twisted joint most commonly used, its nature being apparent without further explanation. When, for any particular reason, it is

Fig. 31.—Cables bound together with Fine Wire.

undesirable to twist the wires, a joint similar to Fig. 31 can be employed. The cables to be joined are simply laid side by side with the ends slightly turned up, and bound closely together with tinned copper binding wire. Either style of joint requires soldering up solid, superfluous solder being wiped off while still hot, and any sharp points or ends of wire that might cut through the insulation filed flush. Taping is done after all flux, filings, etc., have been removed by washing. The most convenient material for this purpose is one of the special adhesive insulating tapes. Formerly a layer or two of pure or vulcanising india-rubber tape was wrapped round

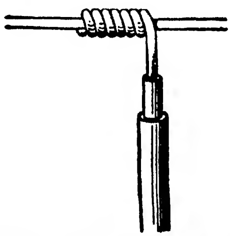


Fig. 32.—T-joint in Solid Conductor.

the splice, followed by ordinary compounded black non-adhesive tape, and the joint painted over with shellac to keep the tape on. This somewhat messy process has now been superseded by using adhesive

rubber-treated linen tape, which when closely and evenly wrapped round the joint adheres firmly, and forms a good waterproof job, at the same time possessing a fairly satisfactory insulation resistance. Short lengths

Fig. 33.—Seven-strand Cable Stripped.

only of tape should be used, wrapped spirally round the joint first in one direction and then in the other, each turn half-lapping the preceding one. Begin on the parts of smallest diameter, levelling them up to the next step, and finally two layers of tape should finish off the splice by overlapping the original insulation an inch or so on either side of the cut portion, the final diameter being but very slightly increased. A little practice will teach more than several pages of instructions. A T-joint in a solid conductor is quite a simple matter, and is illustrated in Fig. 32.

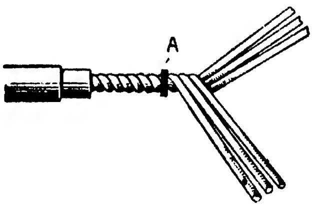
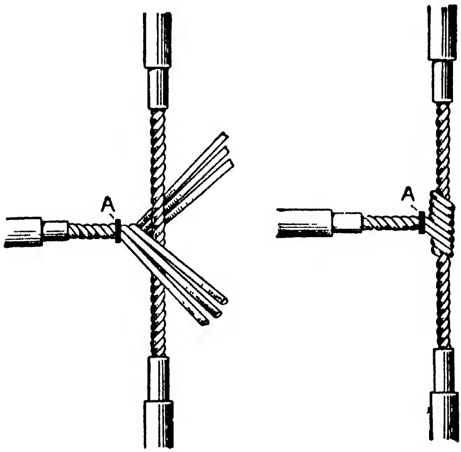


Fig. 34.—Wires of Branch Cable Bent to form Fork.

Joints in stranded cables take a little more time to make, but are quite simple if the following precautions are observed: 3-strand cables are treated in much the same manner as solid wires; 7-strand cables

have the centre wire cut out, and only the remaining 6 spliced; 19-strand cables have the centre wire with the surrounding ring of 6 wires scarfed together, and the outer 12 wires spliced. The successive stages in making a T-joint in a 7-strand cable are shown in Figs. 33 to 36. The main run of cable is prepared as



Figs. 35 and 36.—Making T-joint in Seven-strand Cable.

in Fig. 33, by stripping the covering and thoroughly cleaning the copper from any trace of rubber or dirt. At Fig. 34 is shown the 7-wire branch cable to be jointed on to the main cable (Fig. 33). The centre wire of the branch cable is cut out and the others spread into a fork, each side of which contains three wires. To prevent the whole cable separating, a band of thin binding wire is wound round it at A, and this simple precaution greatly conduces to a neat joint. The method of apply-

ing the cables together is shown in Fig. 35, and the two sides of the fork are twisted tightly round the main cable, forming the condition shown in the finished joint in Fig. 36.

In soldering heavy joints and splices, difficulty is often experienced in getting sufficient heat to run the solder, as the copper conducts away the heat very quickly. When possible, the most satisfactory way to get a sound joint is to immerse the bare metal in

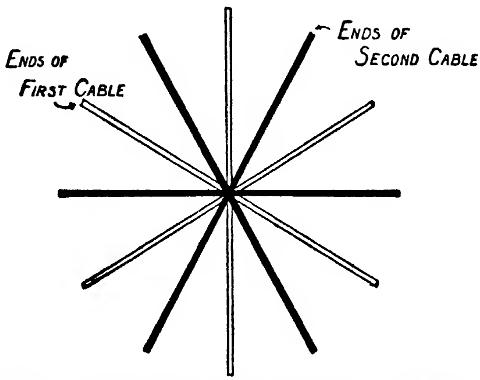


Fig. 37.—Wires in Star Form for End-to-end or Married Joint.

a pot or ladle of molten solder, well fluxed, until it runs in freely, and then at once to quench in cold water. The insulated portion of the wires is of course curved up out of the way, as, if overheated, its insulating properties will suffer. For this reason it is as well to bare a considerable portion of the cables on each side beyond the actual joint, and as additional precaution a wet cloth may be wrapped round these parts. When spliced joints cannot be dipped, a useful tip to get the joint well soldered is to file a deep notch across the face of a heavy

copper soldering bit, in which the cable will lie immersed in a bath of molten solder.

When taping T-joints, remember to continue the tape unbroken from the branch cable to the main run, so as to well cover all angles where moisture might otherwise creep in.

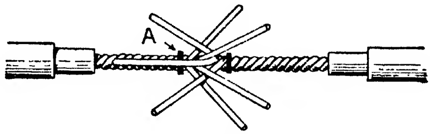


Fig. 38.—Making Married Joint.

An end-to-end, straight-through, or married joint, is illustrated in Fig. 39. The cables are bared, centre wires cut, binding collars put on, all as in preparing for a T-joint; but the wires instead of being forked, are now spread out into star form, with the "rays" interleaved as shown in the white and black diagram, Fig. 37. Note also the binders at A in the diagram, Fig. 38, before the loose ends are twisted up. The completed joint is shown in Fig. 39, and is a very strong one mechanically, when well made.

Fig. 39.—Married Joint Complete.

A recently introduced form of cable-connector which is more easily applied than any method entailing soldering is drawn in Fig. 40. It is quite simple, consisting of a brass or copper sleeve, the bore of which is selected to suit the cable to be jointed; the outer ends of the sleeve are slightly tapered and threaded, and the ends

are also wholly or partially slit. Thus, when the nut is run up, the sleeve contracts and grips the interior cable very closely. Such connectors are made in a

Fig. 40.—Sleeve Connector.

variety of forms, such as straight-through, T-joints 4-way, socket ends, etc., etc., and no doubt form a better job than a poorly made soldered splice.

CHAPTER XII

Self-contained Installations

In a great many instances where electric light would be desirable it happens that there is no public supply, and the only course open is to generate one's own electric power on the premises. In all such circumstances the question of the prime mover or driving power for the generator has to be given the first consideration. All prices in this chapter are pre-war.

The sources of power are many and various, and some will be found more convenient or economical than others according to prevailing local conditions. In nine cases out of ten the decision rests with the question of initial cost, not always wisely, because maintenance and upkeep costs also should receive fair consideration. An installation that costs £10 to instal, and £5 yearly to keep it in running order is a very poor investment as compared with one costing £20 at the start and £2 per annum to maintain. In the choice of motive power, whether wind, water, steam, gas, paraffin, or petrol, one has to be largely guided by local facilities. Where a constant supply of natural water power is available this forms an ideal source of energy; but where water is taken from some supply company's mains it is neither practical nor economical. On the hills and in exposed positions wind power is both attractive and cheap, and is worthy of much greater development than it has received hitherto. Steam

power is but little favoured for private and isolated installations, principally owing to the amount of skilled attendance required, and a certain element of danger from explosion which is absent from most other power systems. Gas, when it is cheap, forms a most convenient motive power, but is of course not available

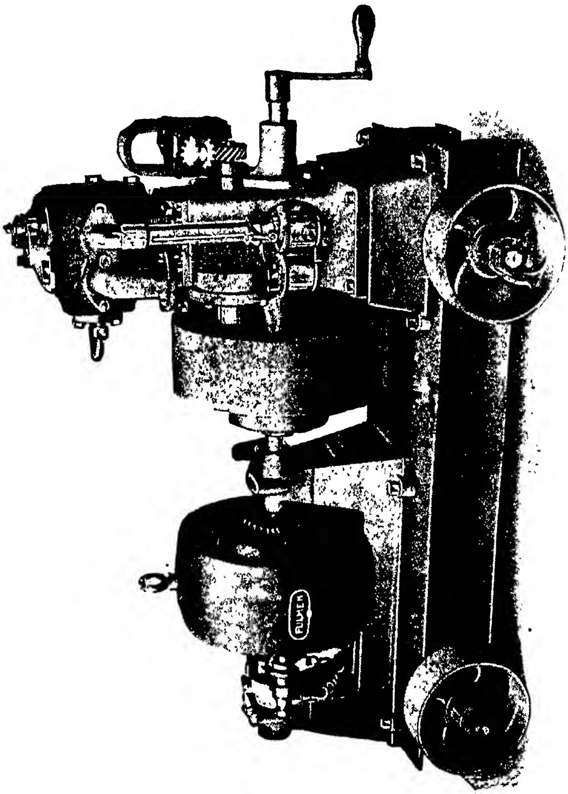


Fig. 41.—Direct-coupled Petrol Electric Set.

outside the town area of distribution; so the most popular sources of power are undoubtedly engines constructed to run on either paraffin or petrol. Very small engines up to about 2 b.h.p. are generally more satisfactory and less troublesome to keep in order when run on petrol, but oil engines prove decidedly more economical as regards full costs. With all engines, whether of the expansion or internal combustion type, two forms are common, the horizontal slow-running, or the vertical high speed engine. High speeds mean increased wear and tear, but they also give increased power, and greatly reduce the weight and floor space otherwise required. Another great advantage presents itself with high speed engines in that they can be coupled up direct with the dynamo and the troubles due to belting eliminated. An example of a modern direct-coupled lighting set arranged to run either on paraffin or petrol is shown in Fig. 41. For stationary work such an outfit as this would be bolted down permanently to a concrete bed, but for portable use—travelling cinematographs, field work, and the like—trolley wheels as shown in the illustration can be easily added.

With all electric lighting plants of whatever type or extent the question of cost is so intimately related as to be inseparable when considering the merits of the scheme. For this reason it is proposed to give a few concrete examples of a large number of lighting schemes that have been prepared to suit widely varying requirements. The following pages, therefore, will be devoted to the analysis of various methods of lighting, on various scales, and with various sources of motive power. In each instance the approximate cost of the principal items is indicated in order that the reader may obtain a better idea of the magnitude of the undertaking he has in mind.

LIGHTING FROM PRIMARY BATTERIES

A large proportion of amateurs who possess a few Leclanché cells for a bell circuit become smitten with the idea that their batteries will do nicely to light their house with also. Let it be clearly understood, however, that efficient domestic lighting from primary batteries of any shape or form is quite impracticable. For lighting single rooms with small lamps used intermittently certain types of primary batteries are more or less serviceable, but as all of them possess a low E.M.F. and none gives even an approximately constant current, they are of no real service where more than one or two candle-power is desired. For bedroom night-lights the "Hellesen" dry cell is one that will give as much satisfaction as any, but three of these will be required to light a 4-volt 2-c.p. metal filament lamp, the cost of the batteries being 17s. 6d. Such an outfit may run for a year without renewals if used for about a quarter of an hour per day.

LIGHTING FROM ACCUMULATORS

Wherever it is possible to get secondary batteries (or accumulators) recharged locally at moderate rates, electric lighting on a small scale can be carried out most conveniently by their means in preference to primary batteries. Owing to the spread of the motor-car industry and the numerous repair shops to be found all over the country, most of which have a charging plant for dealing with ignition cells, it is usually easy to arrange for a regular re-charge to a portable battery at a moderate cost; and this avoids all the trouble, mess and expense attendant upon a primary battery. For instance, supposing four bedrooms on the same floor each required a small intermittent light each evening, matters could conveniently be arranged as in the diagram presented by Fig. 42. One 2-c.p.

or 3-c.p. lamp in each room will suffice. Each lamp would only be alight a few minutes at a time, and not more than two lamps in use together. The lights are shown controlled from one room, a small distribution board B being fixed in this room, with separate leads running to each lamp C, current being supplied to the distribution board from an accumulator A. The approximate cost of the whole outfit will not exceed

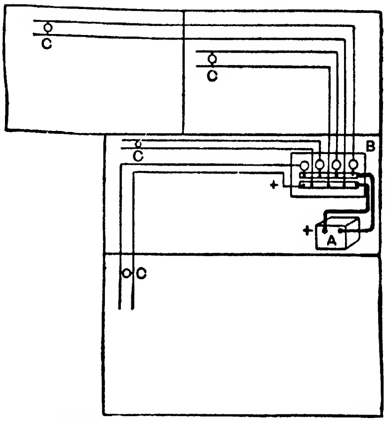


Fig. 42.—Lighting Four Bedrooms from Accumulators.

50s.; the accumulator (4 volts 30 amperes) costing 25s., lamps (4-volts 3-c.p. Osram) 1s. 9d. each, distributing board 9s. 6d., lampholders 6d. each, wires 2½d. per yard. The accumulator will supply thirty hours light to one lamp with one charge.

Of course, a very brilliant light cannot be expected from a 4-volt accumulator, but two 4-c.p. 4-volt lamps would give a fair bedroom illumination in any room not exceeding 12 ft. square.

To light a whole house from portable accumulators

requires something more elaborate and very much less portable than the above example, and as a general rule cannot be recommended unless the means to recharge the cells when exhausted are contained on one's own premises; but there are numerous cases where temporary or localised lighting can be very conveniently and economically carried out by the aid of portable accumulators. A shopkeeper, for instance, may wish to make a special display in his window at Christmas time, and quite a brilliant effect could be secured with the

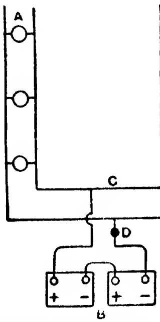


Fig. 43.—Shop-window Lighting from Accumulators.

arrangement shown by Fig. 43, and the judicious disposal of half a dozen 8-volt 8-c.p. lamps and reflectors. The reflectors are so arranged as to screen the direct rays of light from the eye, and throw them on the goods in the window. Two 4-volt 40 ampere-hour cells would light all these lamps for five hours continuously on one charge. In Fig. 43, A represents the lamps, B the cells, C the wiring, and D the switch and fuse. The cost of this outfit with lamps batteries and fittings would be £3 10s.

Similarly, a small cottage or bungalow could be sufficiently illuminated by three 12-volt 16-c.p. lamps

supplied with current from a portable three-cell ignition-type accumulator of 30 ampere-hour capacity. Twelve to fourteen hours' light is obtainable thus at a cost of 1s. 6d. or so for recharging the cells when exhausted. The method of wiring is shown in Fig. 44. A represents the 12-volt battery (three 4-volt cells in series), B the lamps, hung from 3-plate ceiling roses E, and connected with switches C giving separate control to each lamp. A fuse is advisable also as at D. 70/40 twin flexible

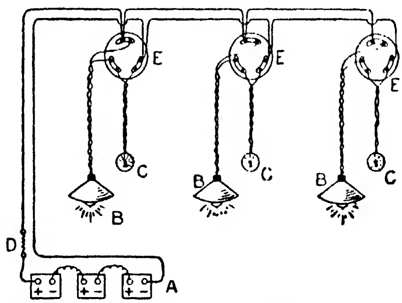


Fig. 44.—Cottage or Bungalow Lighting from Accumulators.

wire can be used throughout for connections, threaded through porcelain bushed screw eyes, and the complete outfit would not exceed £4 15s. in first cost.

LIGHTING FROM WATER POWER

The occasions where a water supply of adequate volume for dynamo driving is present in England are so scarce that a passing reference only is needed to this system. It has already been pointed out that water supply taken from the public mains is not a practicable proposition except for experiment and miniature effects. Where a considerable volume of water is available, however, with a low head or pressure, an undershot wheel of the Poncelet type may be employed. For

high falls and smaller volumes the Pelton type wheel is usual. As every case would have to be considered on its own merits, no really useful generalities can be offered. An instance of cottage-lighting by electricity, making use of a small stream running near by, will serve to outline the general procedure and method of

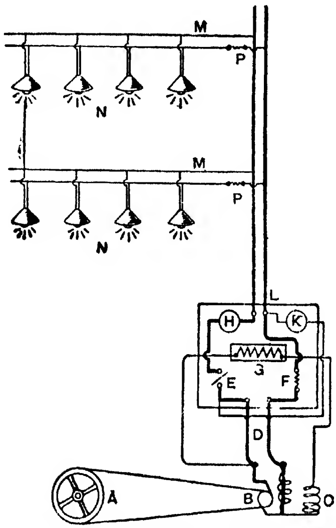


Fig. 45.—Electric Lights from Water Power.

estimating the power available. In the case under consideration the sectional area of the stream amounted to 4 sq. ft., and the rate of flow was three miles per hour. This is equivalent to a flow of 88 ft. per minute, and the volume of water therefore approximated 352 cub. ft., or 2,194 gallons per minute. The weight of water being 10 lb. per gallon, 21,940 multiplied by the efficiency of the wheel and divided by 33,000, represents

the actual brake horse-power of such a stream, namely, about $\frac{3}{4}$ b.h.p., or sufficient to run a dynamo of 300 or 400 watts capacity. Such installations as these are very satisfactory when the water supply does not suffer in dry seasons, because the driving power is always steady and constant day or night. Accumulators, therefore, become unnecessary and fluctuations in the light are avoided by winding the dynamo as a compound machine so that the volts remain constant irrespective of the number of lamps alight. Fig. 45 shows how simple are the switching arrangements and wiring in a case like this. A represents the water wheel belted to the dynamo B; D are main leads to the switchboard, which contains single pole switch E and fuse F, an ammeter H, and voltmeter K. The field regulator G in series with the shunt coils C of the dynamo is not absolutely necessary if the machine is compound wound, but it is a convenient way of adjusting the voltage should the speed of the water wheel fluctuate; L shows the branch mains to the lamps N N, arranged on sub-circuits M M and protected by fuses P P.

LIGHTING FROM WIND POWER

In all cases where the motive power is derived from windmills, the actual lighting should be done from cells, the dynamo being used for charging purposes only; wind power is too variable in England to ensure a steady and regular light otherwise. Taking average conditions all through the year, an eight-mile wind can generally be counted upon for several hours daily in a favourable locality not less than 500 ft. above sea level, but there will of course be days of calm, and the cells will have to be of sufficient capacity to bridge over such gaps. The actual power required for driving say a 10-light dynamo will be relatively small, $\frac{1}{2}$ h.p. being ample, but it is not advisable to instal a mill with

vanes of less than 10 ft. in diameter. As regards the dynamo, this should be of the enclosed type, 35 volts 7½ amperes capacity, four-pole, with self-oiling bearings and carbon brushes, the fields being differentially-compound-wound, so that a rise of voltage due to increase in speed at any time is counteracted by the opposing effect of the series field coils. This avoids overcharging the cells. It will need gearing up from mill shaft to dynamo shaft in the ratio of about 10 to 1. To prevent the cells discharging when the speed falls below the limit, an automatic voltage cut-out is required, which, when the dynamo voltage falls, cuts out the charging circuit. Fourteen cells will be needed of not less than 100-ampere-hour capacity, and to avoid waste of current these should be placed in or near the building it is desired to light. Use 25-volt lamps of 10- or 16-c.p., taking current from a distribution board with a selective four-way switch so as not to over-run the lamps. A voltmeter fitted to the same board will be useful, as showing the condition of the cells and approximate amount of charge in them.

During the daytime, the dynamo would be employed charging the cells (when necessary). At night a change-over switch on the main switchboard would put the lamps on to the cells and disconnect them from the dynamo circuit. Such an arrangement is shown in Fig. 46, which is without reference to the actual relative positions of the instruments, but merely explains their interconnections. The dynamo A, driven from the windmill, has a shunt coil B in circuit with an adjustable resistance C, and also a series winding R opposed to the effect of B. When current increases, the tendency therefore is to demagnetise the field and keep the charging rate more constant; D is a double pole change-over switch, E E a double pole circuit switch, F F fuses, M the battery, and G the cell-regulating switch, H is an ammeter, K

a voltmeter, N N the busbars of the distribution board, and P lamps.

A larger and more elaborate scheme such as would be useful on a dairy farm or for colonial use would be laid down somewhat on the following lines. The mill, of the circular multi-vane derrick type, should be erected on the highest part of the estate, together with the dynamo. Current is then carried overhead or underground, as most convenient, to the battery of accumulators, which should be situated as near the centre of distribution as possible. It is assumed that about 2 to 3 h.p. is needed for small electric motors driving various agricultural machinery by day, and about six 16-c.p. lamps will serve for illumination by night. The scheme is to be fully automatic in action; that is, the wind motor is expected to keep the cells fully charged from the dynamo, automatic arrangements being interposed to ensure that damage through under- or over-charging shall be avoided.

A 16-ft. wheel should be provided, which, with a 15-mile wind, will give $2\frac{1}{4}$ h.p., or more in proportion to wind velocity, and the dynamo best suited to this is one of 2-kilowatt capacity, capable of 50 per cent. overloads for six hours at a stretch.

As regards the pressure of supply, the requirements of economical transmission demand a fairly high voltage, while on the other hand the battery of accumulators will be needlessly expensive if too many cells are erected. Probably the best balance between these conflicting requirements will be to instal a 100-volt battery of accumulators and a 150-volt dynamo; this latter figure allows for the requisite surplus of charging over battery pressure, and for the inevitable drop of pressure along the line. An automatic cut-in and cut-out in the battery circuit protects the cells from discharging backwards through the dynamo should the wind fail, while

a special differential winding on the dynamo prevents the voltage rising sufficiently to overcharge the cells. A further device could be added at will, by which the dynamo is cut out of action altogether when the battery is fully charged.

The remainder of the scheme is fairly simple, and

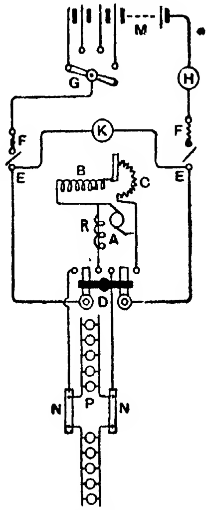


Fig. 46.—House Lighting from Wind Power.

includes shunt-wound motors and starting switches, lamps, cables, usual fittings, and a control switch-board.

On the basis of the foregoing, the following estimate has been prepared, with full specification, for the benefit more particularly of Colonial readers :—

One 16-ft. wind motor mounted on a tower 30 ft, high, including the necessary vertical shafting, bearings platform and ladder, and set of spares. Framing of

galvanised iron, self-oiling bearings, cut gears, regulating and controlling governor, etc.; price complete £65 10s.

One 2-kilowatt dynamo, with differential windings, self-oiling bearings, generating current at 150 volts at normal speed, geared to motor shaft, fitted with carbon brushes, fixed position of commutation at all loads, and capable of 50 per cent. overload continuously for periods of six hours. To be boxed in completely and adequately protected from dust and moisture; price complete £42.

One control switchboard, containing one volt-meter, two ammeters, automatic cut-in and cut-out, double-pole switches and fuses, multiple-way accumulator switch, voltmeter switch, the whole mounted on enamelled slate board with teak battens complete and all connections made; price complete £15 16s.

One battery of accumulators, consisting of fifty-five cells complete in lead-lined wood boxes, with spray plates, trays, insulators, terminals, etc., capable of running a 3-h.p. motor continuously for five hours at full load on one charge, or about ten hours on intermittent load; price complete £91.

One totally enclosed motor of $\frac{1}{8}$ b.h.p. complete with pulley, wound for 100 volts, £5 6s.; motor starter for same, £1 9s. 6d. One totally enclosed motor, 3 b.h.p., complete with pulley, £38; slide-rails, 16s.; motor starter, £1 10s. 6d.; 600 megohm-grade main cables, 7/18, for conveying current from dynamo to cells, £48 per mile; 600 megohm-grade main cables, 7/15, for conveying current from cells to motors, £91 per mile. Branch cables, 7/21½, for lamps, £27 15s. per mile.

Lamps, Osram, 2s. 3d. each; carbon filaments, 1s. each; lampholders, 8d. each; shades, enamelled iron 6d. each, fancy glass 1s. to 3s. 6d. each; ceiling

roses, 6d. each; twin flexibles for pendant fittings, 4d. per yd.

The foregoing figures have been computed on the basis of sound and really reliable goods, having full regard to the difficulty of obtaining spares or replacements in the circumstances in which they will be put to work. The prices stated include free delivery to nearest English port of all goods carefully packed for shipment. The maintenance and depreciation charges on a plant of the above nature should not amount to more than 10 per cent. per annum on the capital outlay, if properly set up and intelligently worked.

MISCELLANEOUS SOURCES OF MOTIVE POWER

It is frequently imagined by non-technical people that a clockwork motor forms an ideal drive for a small dynamo; or a train of wheels actuated by a falling weight ought to be a handy means of lighting the house. Worse still, the question is sometimes asked: "Can a dynamo be driven from a motor, for the purpose of lighting lamps, the said motor being supplied with surplus current from the dynamo?" This is quite a common error in supposing that the electrical energy consumed by a motor when driving a dynamo is less than the energy given out again by the said dynamo for lighting purposes. The loss in converting electrical power first into mechanical power and back again to electrical power by such an arrangement as suggested would waste at least 50 per cent. or 60 per cent. of the initial energy supplied to the motor; so that the latter would be far better applied if used to furnish light to the lamps direct instead of through the medium of motor and dynamo.

To illustrate the futility of such an arrangement, let the following example be considered: A dynamo is supposed to develop an output of 746 watts (one

electrical horse-power); how much mechanical power would result by supplying this input to an electric motor? Theoretically, the conversion from electrical to mechanical power is 746 watts per horse-power, but this cannot hold good in practice, as there are various losses by heat and friction, etc., in an electric motor, whereby some of the electrical energy supplied to it is lost. The less waste of energy in a motor the higher its efficiency, but the best and largest machines made still waste a small percentage, and the smaller the motor the more evident such losses become. A motor of 1 h.p. would be considered of good design if it possessed 85 per cent. efficiency; and consequently if supplied with exactly 746 watts, would only develop $\frac{85}{100}$, or a trifle more than four-fifths of a horse-power at the pulley, which would obviously be insufficient to produce an output of one electrical h.p. (746 watts) in the dynamo again, even were there no loss of efficiency in that quarter also.

Manual labour, again, as motive power is never a very successful idea, as the labour is too great for a steady light to be maintained more than a few minutes at a time. In the East where native labour is very cheap, accumulator-charging is sometimes accomplished thus by frequent changes of gangs, but it is never successful for lighting direct.

CHAPTER XIII

General Arrangements for Private Installations, Factory Plant, and Miscellaneous Circuits

FOR whatever purpose the plant may be installed it is necessary to decide at the outset whether a system of direct lighting from dynamo to lamps will be chosen, or a battery put down as a reserve supply when the dynamo is not running. In nearly all instances, the latter is found far more convenient than running the engine throughout the night just for the benefit of an occasional demand for light; and, except in factory installations where the light is only needed when the machines are running, battery-plants would be the rule rather than the exception.

The question then resolves itself into (1) size of plant necessary, (2) cost, and (3) erection and wiring. Several examples dealing with typical cases arising in actual practice will be given in this chapter, the estimates of costs being put at the lowest advisable scale. Cheaper plant can always be purchased when circumstances render it necessary, but the result is so often disappointing as to render such a course very doubtful economy.

A miniature installation for lighting, say, three rooms cheaply, without the expense and complication of accumulators, could be planned on the following lines:—

A ½ b.h.p. petrol, gas or oil engine is about the smallest that will run steadily and satisfactorily without an undue amount of attention, and will with direct lighting, give the equivalent of about 120 c.p.

A surplus of power is highly desirable as it conduces to steady running and avoids the troublesome "flicker" in the lights which happens when a four-cycle engine is heavily loaded. The engine should, of course, be fitted with two heavy flywheels, and the dynamo likewise may have a flywheel pulley if adapted to take the extra weight on the bearings. Bolt both engine and dynamo to a concrete foundation, and drive with either a leather link belt, or an endless "Dick's" canvas belt spliced by the makers to avoid the jump which would be caused by fasteners or laces. A small main switchboard should be fixed near the dynamo, wired similarly to the illustration on p. 99, containing ammeter, voltmeter, and d.p. main switch and fuse; also, a shunt rheostat is an advantage. From the main switchboard leads will be taken to a central point in the system of wiring, where a distribution switchboard with a switch and fuse to control each lamp circuit may be placed. Or, if preferred, the distribution board can be fitted with fuses only, and each lamp controlled by a switch situated near it, or by a switch lampholder; 20-volt Osram lamps of 10 c.p. will be suitable, the lamps being suspended from ceiling roses in positions according to the required distribution of light. The dynamo should be able to provide 25 volts 5 amperes, to allow for the

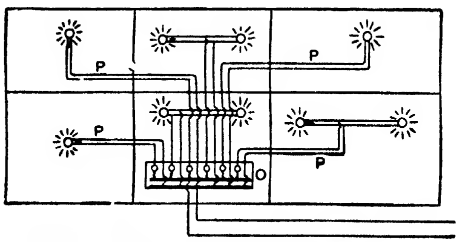
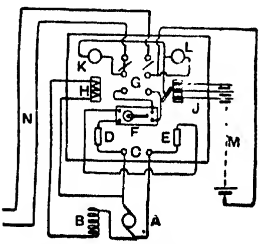


Fig. 47.—Wiring for Small Installations.

slight loss of voltage in the leads when all the lamps are on. The cost of a plant of this capacity would be £20. (All prices in this chapter are pre-war.)

An economical and satisfactory outfit of the same capacity as the above, but with a battery as stand-by during the time the engine is idle is described below :—A small petrol, gas, or oil engine of ½ b.h.p. capacity is put down in a convenient outhouse, driving a 30-volt 4-ampere shunt-wound dynamo. This is used for the purpose of charging a set of thirteen 2-volt 36-ampere-hour accumulators, which can be put in the same shed as the engine and dynamo, but partitioned off. A charging board containing main switch and fuse, ammeter, voltmeter, automatic cut-in and cut-out, and change-over switch is required. The cells will be charged during the daytime, while at night the change-over switch puts the cells on to the lamps. A small distribution board would be wanted at the point where current enters the house, and is conveniently placed in the hall, the lamps in each room being controlled from six switches thereon. The cheapest way of running the cables is to fix them to the wall with small porcelain cleats; or they may be threaded through screw eyes bushed with porcelain. The method is perfectly safe for low voltages, although not so neat, of course, as running the wires in casing, or better still Simplex steel conduits. For a small plant like this, however, it will be quite satisfactory and save half the labour and cost of wiring. The size of the main cables from dynamo to cells and to distribution board will be 7/21½. Branch circuits to each



(*Continuation of Fig.* 47.)

room may be 1/18, if the distance is not too great. A diagram of the necessary wiring and connections, etc., is given by Fig. 47, in which A represents the dynamo, B the shunt coil on field-magnet, C the dynamo terminals on board, D the main switch, E the main fuse, F the automatic cut-in and cut-out, G the two-way change-over switch, H the dynamo regulating rheostat, J the three-step accumulator switch, K the ammeter, L the voltmeter, M battery of cells, N the leads from engine room to house, O distribution board, and P P P P individual lamp circuits. The battery will increase the foregoing estimate of cost by £12.

The question sometimes crops up as to whether the installation of a private plant on one's own premises would not prove cheaper than obtaining the supply from outside sources. With electricity at 5d. per unit, and oil fuel for motive power at 7d. gallon, there is not much advantage on either side to be urged. But there is undoubtedly a great convenience in having one's own plant available at all times, and in being quite independent of outside sources, and there are very many such small installations running satisfactorily in cases in which actual comparative cost does not weigh so much with the owners as the much greater convenience of the independent system. The house wiring would, of course, be equally suitable for either system, provided the voltage of supply is kept the same Meter rent and such-like dead expenses are also avoided with a private installation, and there is no reason why, with careful management, the private plant should not prove to be as economical as the public supply.

In substituting a private plant for an electric supply hitherto taken from the public mains, the dynamo and cells would be installed in a convenient part of the building, and the service mains from the public source replaced with one's private cables from the

accumulator, which would be charged during the day-time and switched over on to the house circuit at night. The diagram presented by Fig. 48 shows the necessary wiring, the letter references being: A the dynamo; B the shunt field-magnet coils; C the shunt regulator; D the change-over double pole switch; E the double-pole fuses; F the five-way charge and discharge accumulator switch; G the ammeter; H the battery of cells

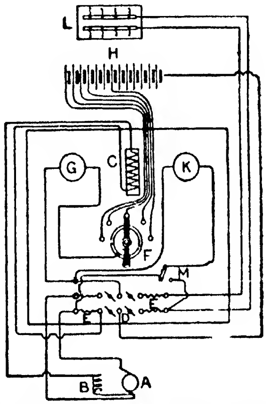


Fig. 48.—Small Installation with Accumulator.

arranged with four end regulating cells and one intermediate point at about half pressure in order that the lamps may be dimmed when required. K is the voltmeter, and M the two-way voltmeter-switch to read both the dynamo and cell volts, while L represents the distribution board with busbars and four double-pole fuses and circuits. When charging, the change-over switch D is thrown over on to the left hand contacts, and when lighting to the right-hand side.

An instance of considerable saving effected by changing over from public to private supply is illustrated in

the following case. Forty lights are involved, the building being a fairly large one with feeders supplying distribution boards on each of three floors. In a case of this kind, one would certainly be justified in putting down a private plant and using oil as a motive power. The plant in its simplest form would consist of a dynamo of 40-light capacity (say 110 volts 25 amperes) driven by a $4\frac{1}{2}$-b.h.p. oil engine, and a lighting switchboard containing ammeter, voltmeter, D.P. switches and fuses, and shunt rheostat. This is the most economical lines on which such an installation could be laid out. Of course, a battery of accumulators would be a convenience, as avoiding the necessity of always running the engine when light is desired, but the initial cost would be much higher than the cost of direct lighting from the dynamo, and the sizes of the dynamo and of the engine would be somewhat increased. The greatest point in favour of a battery is the reserve of electricity that can be used in case of a breakdown; but with a really reliable and properly erected engine and dynamo, the contingency is a remote one, and may be neglected. The purchase of a cheap engine or dynamo is the worst possible policy, and is most expensive in the end. The premises should be wired on the distribution board system, as shown in Fig. 49, taking care that no individual circuit carries more than 5 amperes, and that all arc and incandescent circuits are kept separate. The wires should be run in Simplex or other similar conduit, and the fittings wired on the looping-in system, in order to avoid soldered joints. A fair average cost for good work is given below: $4\frac{1}{2}$-b.h.p. oil engine, £55; 40-light dynamo, £30; switchboard, £8; wiring about 30s. per point, according to the style of the fittings and the distance. The letter references are: A dynamo (shunt or compound wound); B, shunt coils; C, ammeter; D, voltmeter; E, shunt rheostat or voltage

regulator; F, F, main double-pole fuses and switches; G G, mains feeding distribution boards; H, H, H, distribution boards; J, J, J, lamp circuits.

A brilliant light is, above all things, essential to shopkeepers, who rely on a good window display to attract the passers by. No one will enter a badly-lighted shop, however well the windows may be dressed. Tradesmen have to contend against unusual fire risks, and therefore it behoves them to be extremely careful

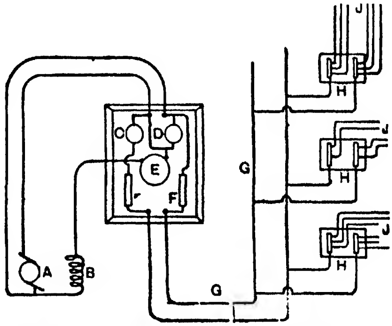


Fig. 49.—Distribution-board System of Wiring from Dynamo.

that not only a brilliant but a perfectly safe illuminant is used. The most convenient and least expensive means of carrying out small shop-lighting installation is by means of a combined "petrol electric" set, consisting of a $\frac{1}{2}$-h.p. petrol engine direct-coupled to a slow-speed 25-volt 10-ampere dynamo, on a single bedplate with ignition gear, tanks, etc., all self-contained and portable. Such a set will cost £20 complete, ready for erection. The cost of fuel is very small, and the depreciation may be set at about 12 per cent. to 15 per cent. on the prime cost per annum. With the immense advantages offered by metallic filament lamps these

small sets are coming greatly into use, as they will fully light the equivalent of 200 candle-power in either 8-, 10-, 12-, or 16-c.p. 25-volt lamps. In addition to the cost of engine and dynamo, allowance must of course be made for wiring the lamps, which in most cases would amount to 11s. to 14s. per lamp, according to style of fittings, using Simplex steel tubing and fittings throughout, such as would be approved by any first-class fire insurance office. Electric light is by far the safest of all illuminants when properly installed, but it is a very poor policy to wire buildings in the cheapest possible style, running the wires without adequate mechanical protection, as not only is the risk of fire considerable, but depreciation then becomes a heavy item. The depreciation on wiring and fittings in a properly erected plant ought certainly not to exceed 5 per cent. of the initial cost: Where there is sufficient basement room, and especially when more or less exposed to the public view, it may not be inadvisable to instal an engine of the horizontal slow-running type, a belt-driven dynamo, main switchboard, etc., all mounted in a neatly arranged room lined with glazed tiles. The "drawing-power" of such as an advertisement is considerable. For example, adequate lighting arrangements for three large show-rooms, 30 yd. by 10 yd., would follow on these lines:

Assuming a particularly brilliant light is required, Osram lamps should be used, allowing 1 c.p. for every 4 sq. ft. floor surface. This fixes approximately the candle-power required, since floor area divided by candle-power per square foot gives total candle-power. In this case 30 yd. $\times$ 10 yd. $=$ 300 sq. yd., or 2,700 sq. ft.; and 2,700 $\div$ 6 $=$ 450 c.p. per room. Using 50-volt Osram lamps of 16 c.p., twenty-eight lamps per room are required; and for three rooms a total of eighty-four lamps. Allowing 20 watts per lamp as

necessary for energy and cable losses, a total electrical consumption of 1,680 watts is found necessary, representing the maximum load; that is, when all the lamps in all the rooms are alight at once. If only one or two rooms are in use at any one time, or a portion only of the lamps in each room, then this figure can be reduced accordingly, as well as the initial cost of the installation. It is, as a rule, much better, however, to allow for contingencies such as extensions, and not cut matters too fine when first laying down the plant.

For the above eighty-four lamps, the following plant will be needed, the cost of which has been estimated on the basis of good, reliable machines suited to the work, and requiring a minimum outlay for upkeep: A shunt-wound dynamo of 55 volts 36 amperes (2 kilowatts), with slide-rails, self-oiling bearings, carbon brushes, fixed position of brush gear at all loads, and preferably of the 4-pole slow-speed type, costing £30. If gas is available, a horizontal-type gas engine will be the most convenient means of driving it, and the engine should not be of less than 3½-b.h.p. capacity, of the high-speed type, governed, with electric ignition, or porcelain tube ignition. Such an engine will cost about £37 complete with water vessel, silencer, etc. For the necessary belting, concrete foundations, pipe connections, etc., allow another £5 to £6, according to local labour facilities.

A plain switchboard is necessary, containing ammeter, voltmeter, double-pole fuse, and double-pole switch; price on enamelled slate £6 10s. From the main switchboard feeders or main cables consisting of 7/14 600-megohm grade costing 1s. 6d. per yd. must be run to distributing switchboards, of which there will be three required, one in each room, arranged as on p. 113. These should have at least two circuits, and preferably three, on which the lamps are grouped in equal numbers,

each circuit carrying not more than 5 amperes, and each protected by a double-pole switch and fuse placed on the distribution board. Allow 18s. 6d. each as cost of distribution boards, and wire up the branch circuits to the lamps with 3/21 cable throughout, at 4½d. per yd., looping in the cable. Osram lamps will cost 3s. each, and, although expensive, it must be remembered they will save quite two-thirds of the power otherwise required, which will tell up greatly as regards the initial cost of the installation. Lampholders at 8d. each and wood casing or Simplex conduit to run the cables in at about 5s. per light, will cover all the other expenses except labour.

A total depreciation of 10 per cent. to 12 per cent. should cover the whole installation, allowing for interest on capital outlay. The small cost of attendance and fuel will soon effect a large saving in an installation of this size over any other method of illumination.

The cost of a smaller installation on the same lines but proportioned to suit about twenty lights, would work out as follows:

The necessary machines are a gas, oil, or petrol engine of 1½-b.h.p. capacity, a shunt-wound 500-watt dynamo of 30-volt 16-ampere output, a plain dynamo switchboard, twelve Osram lamps of 25 volts 16 c.p., and about eight lamps of 32 c.p. Also the usual fittings in the way of lampholders, wire shades, switches, etc. The dynamo and engine should both be mounted on a substantial concrete bed, not too close together, so as to give a fairly long belt drive. The engine should be of a modern high-speed type with two flywheels and sensitive governors; the dynamo to have slide rails, self-oiling bearings, and carbon brushes. The current generated by the dynamo is first led to the switchboard, which is fitted with ammeter, voltmeter, main switch, main fuse, and rheostat; the main cables are then taken

from the switch board to a distribution board located at about the centre of the network of lamps and about five or six " ways " or poles provided to the distribution board, from each one of which a branch cable is led, supplying three or four lights. Individual lamps can be controlled by separate switches, or key lampholders, and the cables run either in wood casing or steel conduit. The cables required will be 7/16 for the mains, 7/21½ for branches, and 1/18 for single lamps (or 3/22). Cost of engine, £22 ; dynamo, £12 ; switchboard, £5 ; lamps, £3 ; cable, according to length ; wiring and fittings about 15s. per point, according to length of run.

A somewhat interesting instance of the adaptability of electricity not only for private or commercial illumination, but for church lighting, organ-blowing, and the lighting of schools, and public buildings occurs in the undermentioned estimate and specification :—These buildings, previously lighted by gas, had to be converted for electric lighting, using as far as possible the same fittings, not good practice perhaps, but sometimes unavoidable. For the church forty-three lights of 16 c.p. are to be allowed ; vestries and porch, eight lights ; first school, twenty-two lights ; second school, twenty lights ; and a surplus of power for the motor equal to 500 watts. Total 102 lamps, using 20-watt 16-c.p. 100-volt metal filaments ; total power, inclusive of motor, 2,540 watts. If economy in initial cost is a desideratum, do not instal accumulators ; these can be added afterwards if desired. All things considered a 2½ kilowatt petrol-electric-lighting plant would fill the present requirements most satisfactorily, to the following brief specification :—One 5-in. by 5-in. vertical water-cooled petrol engine, with magneto ignition, tanks, pump, and all fitments, direct coupled to one 2½ kilowatt 4-pole generator, 100 volts 25 amperes compound wound, and mounted on self-contained bed-

plate, £90; 102 metal filament lamps, £11 9s. 6d.; 102 lampholders, £2 11s.; 102 assorted shades, £4 11s.; 20 tumbler switches, £1 6s. 8d.; Simplex or "Stannos" wiring at 15s. per point approx. and 50 points, £37 10s.; switchboard for dynamo, £5 10s.; distribution switchboard, ten-way, d.p. switch and fuse, £5; 25 assorted two-light brackets and 1 large electrolier, £12 10s.; engine foundation, £2; automatic organ motor, £20; making an approximate total of £192 8s. 2d. The arrangement of lights recommended would be somewhat different than with gas. In the church, for instance, the large centre electrolier would be retained, but better general illumination and cheaper wiring would be secured by using a series of two-light brackets round the galleries. As a general rule, grouping of lights into clusters for such buildings is to be avoided, as the glare tries the eyes; and a softer and more generally pleasing illumination is secured by distributing more evenly smaller light units. This is also convenient for switching off portions of the light during intervals of the service. If a high-speed and well-made petrol-electric set such as advised be installed, there will be no appreciable flicker in the lights, while the set will occupy minimum floor space and require very little attention.

A final example must conclude this brief review of the possibilities of electric lighting, under its widely varying conditions and applications. This time a case is selected in which a portable petrol engine is used on a farm for various agricultural purposes, and is impressed into service also for the domestic lighting arrangements when it is otherwise at liberty. As the engine may be away at work on different parts of the farm for some days at a time, it is necessary to put down a battery of accumulators, in order that light may be obtained whenever the engine is on other duty, the accumulators being charged as frequently as possible.

The general scheme of this installation will be as follows: A small outhouse should be appropriated for the electrical installation, not more than 10 yd. or 20 yd. from the house, in which will be placed the dynamo and main switchboard; and also, partitioned off to avoid damage from the acid spray, a battery of accumulators. If convenient, the dynamo pulley or countershaft can protrude from the side of the building, so that the portable engine is simply run up to the spot and belted. Discharging current is conveyed from the battery room to the house by underground or overhead cables, and at the point of entrance is fixed a two-way distribution board. From this point the internal wiring is carried out in two "runs," upstair lights, say, on one circuit and downstair lights on the other, each run being controlled by double pole fuses on the distribution board. Either single or groups of lamps may be separately controlled also by means of switches in each room.

The system of running the wires is largely a matter of taste. Simplex steel conduit is very reliable and popular, or Stannos wiring is preferred by many, and is slightly cheaper. It is not recommended in a plant of this kind to run the lamps direct from the dynamo and charge accumulators simultaneously, but to have a change-over switch fitted to the main switchboard, so that the cells may be charged alone from the engine at any convenient period during the day, and then thrown-over to the house lights, cutting out the dynamo entirely. This simplifies switching arrangements, and renders the plant less likely to get out of order under unskilled management.

The rooms it is desired to light are 12 ft. by 16 ft., and for the majority of purposes one 16-c.p. metal filament lamp will be found quite sufficient. In certain situations 25 c.p. will be more desirable, in others 10 c.p. will be adequate; the average light per room will

therefore be 16 c.p., and there are eight lights required. Adopting a circuit voltage of 25, a convenient figure, and one economical of cells, the full load current with all lamps on will be $6\frac{1}{2}$ amperes, and as several days' store of energy is desirable, it is better to put down accumulators of fairly large capacity. Five hours' light per night at a $6\frac{1}{2}$ ampere rate represents $32\frac{1}{2}$ ampere-hours, and if sufficient storage capacity is desired for one week's supply when fully charged, the cells must have a capacity of $7 \times 32\frac{1}{2} = 227\frac{1}{2}$ ampere-hours. The dynamo should be as large as possible consistent with its being within the power of the engine to drive, otherwise it will take a considerable time to charge up the cells sufficiently for a week's supply. Fourteen cells will be required, and the dynamo voltage will need to be 35 volts to fully charge them. Allowing 500 watts output for every 1 b.h.p. that is, 2,000 watts for the 4-h.p. engine, the dynamo may thus be designed for 35 volts $\times$ 57 amperes, shunt wound, of the 4-pole type. Charging at the rate of, say, 50 amperes, the cells can then be fully charged in one day's run of seven hours, although a lower rate for a longer period would be better for them. The approximate cost of the various items may be estimated roughly as follows :—Dynamo, £30; main switchboard, £14; accumulators, £26; cables, £5; distribution board, £2; wiring, fittings, and lamps, all of good plain quality, about 18s. per point.

CHAPTER XIV

Special Circuits, Etc.

THE question is often asked :—" How do matters adjust themselves when it is desired to charge a battery of cells and at the same time light lamps ? It would seem that the latter must be very much overrun, because every 2-volt cell in the battery requires at least 2¼ to 2½ volts

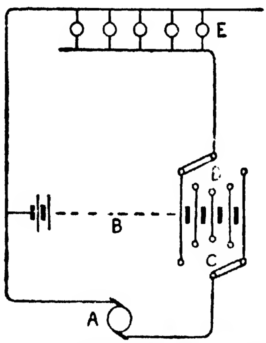


Fig. 50.—Connections for Lighting and Charging.

to fully charge it." If there were no end cells to the battery with their regulating switches, such would be the case, and it would be impossible to fully charge the battery while the lamps were in circuit without considerably overrunning them. If, however, matters are arranged as in Fig. 50, the remedy is obvious. A re-

presents the charging dynamo (no switching arrangements being shown); B the battery of accumulators; C and D charge and discharge multiple-way switches respectively; and E the lamps. If the levers of C and D were both put on the same stud, it is evident current would pass through direct from A to E at the dynamo voltage. When the volts were in excess of the battery, a small charging current would also pass through the latter; in other words, the dynamo would take the lamp load entirely, and at the same time send a small current round the battery circuit. By placing the switches, however, in suitable positions as shown, the maximum pressure on the cell circuit can be maintained between its ends to ensure a full charge, while current at a lower pressure appropriate to the lamp voltage is tapped off at some intermediate point of the regulating switch, the difference between the two voltages representing the opposition E.M.F. of the end cells coming into circuit between charge and discharge switches. The whole dynamo current thus splits up into two parts, that taken by the lamps and that used for charging the bulk of the cells, and the end regulating cells carry the whole of this before it divides into the two circuits. End cells are thus almost constantly in a state of overcharge; but it is common practice, and has to be tolerated in such installations where combined lighting and charging is in vogue.

As a general rule switchboards may be classified into (1) Plain lighting boards; (2) plain charging boards; and (3) combined lighting and charging boards. Illustrations of the first will be found on pp. 103 and 113. A plain charging board would include in addition to the instruments found on the foregoing board, an automatic cut-in and cut-out, which protects the cells from accidental short circuit and damage from excessive discharge, apart from the hand-operated switches.

The principal instruments needed on a plain charging board are shown in the diagram, Fig. 51. A represents the armature of a shunt wound dynamo; B the field coils; C a regulating resistance in series with B; D D a double hole switch; E E double pole fuses; F the series coil of the automatic cut-in and cut-out; G its shunt coil; and H the mercury cups, which close the main charging circuit as soon as the copper bridge is drawn down by

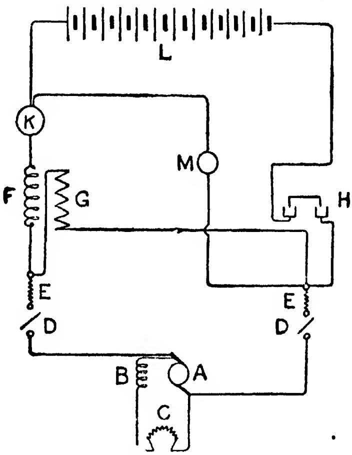


Fig. 51.—Plain Charging Board.

action of coil G. K is the ammeter, L the cells, and M a voltmeter.

Combining the various instruments on the two kinds of switchboards just described gives a slightly more complicated board in the form of the standard combination lighting and charging boards illustrated in Figs. 52 and 53.

The usual instruments required for a switchboard of this class are:—One voltmeter, one two-way volt-

meter switch, two ammeters, two single (or double) pole fuses and switches, one charge and discharge accumulator switch, one automatic cut-in and cut-out, and a shunt field rheostat. These instruments will give the following combinations if wired up as shown in Fig. 52 :—(1) Dynamo A lighting lamps K direct : Place voltmeter switch J on the left hand contact, run the dynamo up to speed, and regulate the field excitation by means of the rheostat C until the correct lamp voltage is obtained; then close the switch D. (2) Charging cells N only: Place the accumulator switch O at the bottom contact on the right hand, and take a reading

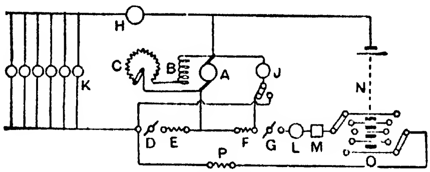
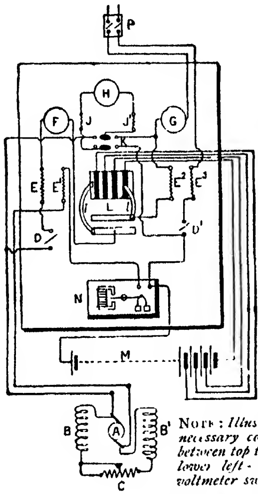


Fig. 52.—Wiring up of Switchboard Instruments.

of the battery voltage by moving the voltmeter switch J to the right-hand contact. Switch O on right completely off now, and O on left completely on, that is, on the bottom left-hand contact. Run the dynamo up as before to normal speed, and adjust the field excitation by manipulating C until the volts are five per cent. higher than those of the battery. Close G, then if no current passes, raise the volts still higher until the automatic cut-in and cut-out M closes the circuit, and note the charging current on the ammeter L. Adjust this until the charging rate is correct by raising or lowering the volts. If the end regulating cells of the battery N gas freely before the rest are charged up, cut them out by moving the left-hand switch O to the top contact, or as required. The cut-out M must be

carefully set so as to break circuit automatically, at a slightly higher voltage than the cells attain at the end of the charge. (3) Lighting lamps K and charging cells N concurrently: Proceed as in (1) and (2), except that the switch O will be on the top left-hand contact and completely off on the right-hand, to avoid overrunning the lamps. This combination also places the dynamo



NOTE: *Illustration omits one necessary connection — that between top terminal* E¹ *and lower left-hand contact of voltmeter switch* K.

Fig. 53.—Wiring Diagram showing Switchboard Panel.

and cells in parallel when O is on the left-hand contact corresponding to right-hand, and the capacity of the plant is doubled so long as the cells retain their charge. (4) Lighting lamps K direct from cells N: Place the switches D and G in the off position, and O on the right-hand contact which gives the nearest desired voltage. In the diagram, B represents the dynamo field coils; E, F, and P are fuses. The ammeter H

indicates lamp current only, and the ammeter L charging current only.

Another diagram giving the same possible switching combinations, but arranged to show the various instruments as nearly as possible in their respective places on the switchboard panel, is given in Fig. 53. In this illustration A represents the dynamo; B and B′ the shunt coils in series with which is an adjustable resistance C for controlling the excitation; D and D′ are single-pole switches (double pole can be substituted if desired, but are not really necessary when using double-pole fuses); E, E[1], E[2], and E[3] are single-pole fuses; F is one ammeter, G another; H is a voltmeter with fuses J and J′, and a double-pole switch K; L represents a four-way charge and discharge switch, with sliding bridges *l*; M is the battery of accumulators, and N the automatic cut-in and cut-out, in this instance the Neville type instrument; P is a double-pole switch controlling the circuit to the distribution board.

From motives of economy it is quite usual to find combination charging and lighting boards fitted with only one ammeter. On the discharge side of the wiring an ammeter is not indispensable, as a fair estimate of the current is easily ascertained by counting the number of lamps alight and adding together their known current consumption. Such a board would be wired according to Fig. 54, which shows the necessary connections between the instruments without reference to their actual positions on the board, for the sake of clearness. A is the dynamo, B its field circuit, and C the adjustable rheostat in series with the fields; D is the main double-pole switch and fuse on the dynamo mains, and N the same fittings on the cell side; E is an automatic battery cut-out with connections of its series and shunt windings shown; P an ammeter in the charging circuit, and F and G; accumulator charge and discharge switches respectively;

H represents the battery, and K a two-way switch by which the battery is thrown into the charging or discharging position according to the requirements; L shows the voltmeter with its two-way switch M reading charge and discharge volts, and P the ammeter.

The same idea is carried out in the following figure,

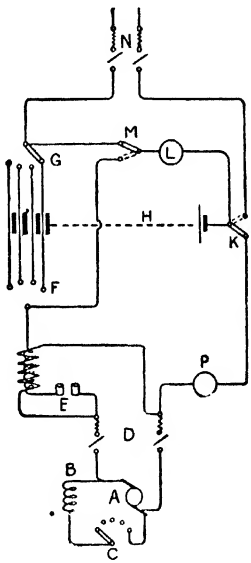


Fig. 54.—Combination Charging and Lighting Switchboard with only one Ammeter.

which gives the full amount of possible combination, namely, dynamo to lamps, dynamo to cells, dynamo to both, and cells to lamps. The chief difference is that the accumulator switches M L are used also as on and off switches to reduce the expense of the board. The diagram given in Fig. 55 represents the con-

nections of the various essential instruments on the switchboard, without reference to their actual positions in practice. A is the dynamo armature; B the shunt coils on its fields in series with an adjustable rheostat C; D and E are respectively the main switches and fuses on the charging side; while S and T represent similar fittings on the discharging or lamp side; G are the

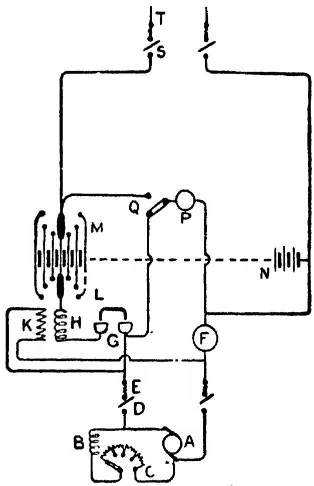


Fig. 55.—Essential Instruments on a Charging and Lighting Switchboard.

mercury cups of the automatic cut-out in circuit with its series coils H, K being the shunt coil of the same instrument; L and M show the charge and discharge multiple-way accumulator switches on the end-regulating cells of the battery N; F is the ammeter, and P is the voltmeter with its two-way switch Q, which shows either the dynamo volts or the cell volts. It will be noticed the board will give the following combinations: Charging

cells only, with D on; lighting and charging simultaneously, with D and S on; lighting lamps from cells only, S on and D off.

Sometimes it is desirable to wire a switchboard so that it can be used for alternative sources of supply; as, for instance, in the event of a breakdown another dynamo may be kept in reserve and switched on to

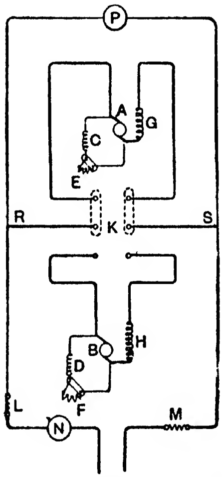


Fig. 56.—Switchboard Wired for Alternative Sources of Supply.

the circuit with the least delay possible. Fig. 56 shows the simplest method of carrying out the above in such a way that there shall be the least interruption to the service. Both dynamos are compound wound, A and B representing the armatures, C and D their shunt coils, E and F rheostats in series with same, and G and H the series coils of the compound winding. It is assumed that the machines are "short-shunt"; if long-shunt

the ends of the shunt field coils now shown coming from the rheostats to the bottom of the armatures would instead be connected to the upper ends of the series coils G or H. In the centre of the diagram is shown a change-over switch K, the top pair of contacts being closed by the switch blades indicated by dotted lines. This connects dynamo A to the outgoing cables R and S. Similarly, if K be closed on to the lower pair of contacts, dynamo A is cut out and B put into service. The outgoing current from either source encounters the same instruments, namely: fuses L and M, ammeter N, and voltmeter P.

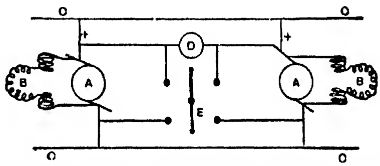


Fig. 57.—Two Shunt-wound Dynamos run in Parallel.

Dynamos, like batteries, can be run in parallel, and when, for instance, the demand for current has outgrown the capacity of the dynamo originally installed, it is quite common practice to put down another machine and in times of heavy load run up the second dynamo to share this load with the first. Fig. 57 is a diagram showing two shunt-wound dynamos A coupled in parallel for lighting, the effect being to double the capacity of the plant as far as current is concerned, the voltage remaining the same. Care must be taken to speed up the dynamos equally, or to adjust the field rheostats B until both machines give exactly the same voltage; otherwise, the entire load will fall on that dynamo giving the higher voltage, and the other may be even running as a motor instead of contributing to its share of the load. C are the mains, D the voltmeter, and E

a two-way voltmeter switch for the purpose of comparing their respective voltages.

It is good practice to introduce separate ammeters into each dynamo circuit, before they unite at the common junction or busbar, as this shows at once whether each machine is doing equal duty.

A great many cases occur when it is desired to charge a few small accumulators from a dynamo giving a much higher voltage, without interruption to the existing switching arrangements, and in as economical a manner as possible. The following directions will meet such instances as the above. Take, for example, the case where say a 200-volt dynamo is lighting a few incandescent lamps as in Fig. 58; obviously it is impossible to put

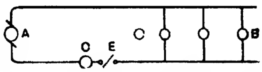


Fig. 58.—Lamps Connected in Parallel.

a 4-volt cell across the mains in just the same way that a lamp would be connected, the dynamo would be short-circuited and the accumulator ruined, unless a large amount of resistance was also included.

But by putting the cell in series in the circuit, instead of in parallel, as in Fig. 59, the same current that issues from dynamo to lamps also flows through the cell on its way, and the latter becomes charged without any waste occurring through the insertion of a large resistance otherwise necessary. The only effect it will have on the circuit is to rob the lamps of a small percentage of their voltage and very slightly dim the light, but where, as in the present example, it does not exceed 2 per cent. of the total volts, the difference in the light will be inappreciable. In these two diagrams (Figs. 58 and 59), A represents the dynamo, B the lamps, C an ammeter, D the cell, and E a switch.

The only drawback to this method of charging is that its application is limited to cases where the current taken by the lamps does not exceed the safe charging rate of the cell. When it does, the only alternative is to have a separate circuit for the charging, quite distinct from the lamp circuit. The difficulty encountered is then the question of what kind and amount of resistance to use in order to reduce the high voltage to a point where it will only just pass the desired current through the cells.

Undoubtedly, by far the most compact and convenient form of resistance for such purposes is to use

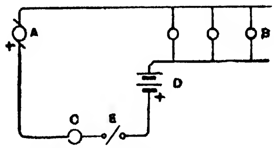


Fig. 59.—Lamps in Parallel. Cell in Series.

ordinary carbon filament lamps of about the same voltage as that of the circuit. If a series-parallel bank of lampholders B is wired up as shown in Fig. 60 to the high voltage mains A A, and busbars D D, it is evident that the only path for current to get to the cells E is through any lamps which may be inserted in the holders at B. It is an easy matter to choose lamps of such candle powers that they each pass a definite amount of current, say $\frac{1}{4}$, $\frac{1}{2}$, or 1 ampere, and it is then at once known what the approximate charging rate may be by counting the number of such lamps at B, each one of which passes a certain quantity of current through E.

Lamps used thus serve the double purpose of resistance and ammeter. Very often the light from lamps used thus as a resistance can be made use of in an otherwise dark corner, whereas a wire resistance, while

occupying far more room, would be of no service at all except as a resistance.

Circumstances might arise when a small light would be a convenience at times when the engine and dynamo,

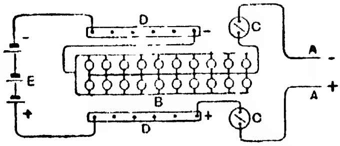


Fig. 60.—Connections for Lamp-resistance.

were not running, and yet not justify the expense of putting down a full battery of accumulators. This might be met in the way shown in Fig. 61. A is the dynamo, used to deal with the regular load of lamps B during the demand for normal lighting. In series with this lamp circuit are a few accumulators C—about five cells for a 10-volt supply being convenient—which necessitate the dynamo A giving about ten volts more than the actual lamp voltage at B. When A is not running, the charge previously imparted to the cells C by the current which passed round B, is now available for night lights in the form of a few

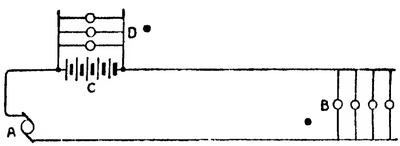


Fig. 61.—Introduction of Small Accumulator into Lighting Circuit.

10-volt lamps at D. No switching arrangements are shown in this diagram, it being the purpose merely to illustrate the principle of working.

Illustrations of similar circuits and special switch-

board wiring might be extended indefinitely, but sufficient examples have been given to indicate the remarkable degree of flexibility of control associated with electric lighting matters. Not only is electricity by far the safest and most sanitary source of light, heat and power, but it is also the most convenient of the modern necessities of life, adaptable equally to all possible exigencies of public or private lighting plants.

CHAPTER XV

Wiring a House for Bells and Lights

A TYPICAL job will now be described—that of wiring a new villa residence, costing about £800 to build (pre-war), for bells and lights.

As soon as the walls of the house are up and the roof on—before any plastering or decorations are begun, in fact—the various runs for the bell-wires should be laid out and the position of pushes, bells, etc., marked off. The same applies to the arrangements for the lighting circuits, for both will be carried out in similar manner on the sunk conduit system, using light gauge brazed "Simplex" steel tubing with socketed joints for both purposes. Each system, however, must be kept quite separate from the other. If the wiring is thus carried out during the erection of the building all tube work can be concealed from view, and any objections on the score of unsightliness removed, as nothing will be visible after plastering but the fittings themselves.

The positions of the lights in each room, and the switches controlling them, should be settled at this stage, and a point located for the distributing centre. Then the local electric lighting authorities are requested to indicate the point where their supply mains will be brought into the house. A copy of their rules and regulations for the guidance of consumers should also be applied for, and any special conditions relating to the

supply of current carefully noted; or the annoying experience may occur of having the company refuse to connect on their mains owing to failure in complying with some necessary condition. These matters are dealt with at length in earlier chapters.

No very stringent regulations apply to electric bell systems; but it is to the owner's advantage to have the job carried out in a workmanlike manner, using the best material and the best system; and for this reason it is recommended to run the whole of the bell wiring also through steel conduits, in preference to stapling it round skirtings, under floorboards, etc., as is often done with a mistaken idea of economy. It is a question of upkeep as well as of initial expenditure, the former being often lost sight of, and without undue expense it is quite possible to put in first-class material and work in such a manner as will prove much cheaper in the long run than inferior material and labour, because it avoids altogether the necessity for frequent replacements and renewals—to say nothing of the annoyance caused by the bells always being out of order.

The general lay-out of the bell system will be considered first. The most frequent source of trouble in nearly all bell systems originates with the wiring; the insulation is often quite inadequate, leakage occurs, and the batteries are always running down as a consequence. It is especially important to select a relatively high grade of insulation when bell wires are run in concealed positions, for although the tubing is a great protection against mechanical injury, it is not an easy matter to withdraw any wires from the conduit without abrading their coverings if they happen to be of indifferent quality.

The standard class of bell-wire for internal work consists of a single No. 20 S.W.G. pure copper wire,

tinned, then insulated first with pure indiarubber, then cotton strands laid lengthwise, this being afterwards lapped with coloured cotton, and the whole finally dressed with melted paraffin wax.

Various coloured cottons are obtainable for the outer coverings, as this forms an invaluable aid in conduit work where a number of wires are bunched together in

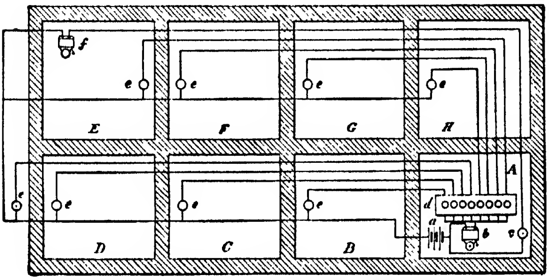


Fig. 62.—General Bell-wiring Arrangement.

one tube. Each circuit can have its own distinctive colour, enabling it to be at once recognised at either end of the run.

Another prolific source of trouble is imperfect jointing, in the shape of badly-made and soldered connections. In "cheap" work a mere baring and twisting together of the wires is only too often found, followed again by insufficient insulation of the so-called joint. It is strongly advisable, whenever possible, to adopt the "looping-in" system of wiring, in preference to soldered joints; it uses up a little more wire, but, on the other hand, reduces considerably the labour costs and ensures an unbroken metallic circuit from end to end, with no weak spots in the insulation. This style of wiring will be understood better on referring to Fig. 62, which is a diagram of the bell-wiring arrangements

for the house in question. The figure shows eight rooms, A to H, representing kitchen, dining-room, drawing-room, and hall, on the ground floor; three bedrooms and bathroom on the first floor, with an outside front-door push. Each room has one push *e* arranged to ring the bell *b* in the kitchen through a pendulum indicator *d*, each opening of which is numbered, or otherwise marked, to correspond with the room calling. Should the maid be upstairs when the kitchen bell rings, she can be called down by the upper bell *f* rung from the kitchen push *c*.

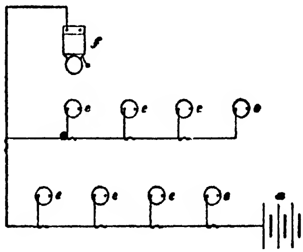


Fig. 63.—Bell Wiring by T-joints (not recommended).

Taking the lower direct run of wire from left-hand terminal of battery *a* to its finishing point at push *e* in room H, it is evident that in the ordinary course of things there would be at least eight T-joints to make, as indicated in Fig. 63. This means eight chances of trouble later on, which can be quite avoided by "looping" the wire in to the various terminal points required, as in Fig. 64, baring it only just where required to make metallic contact. The battery wire, running direct to one side of all the pushes, is now in one uncut length; a white covering is usually chosen for this particular wire, to distinguish it from shorter runs. The remaining wires are each of a different colour,

or combination of colours, which enables them to be easily selected when connecting up each room to its particular indicator hole. The tubing employed is light-gauge Simplex steel, ½-in. internal diameter throughout, in order to simplify the number of fittings required, although it will have to carry various numbers of wires. For instance, the run illustrated in Figs. 63 and 64 will carry one wire only, except where looped back; but the two runs rising from the indicator *d* will carry four and five wires respectively at the start, the

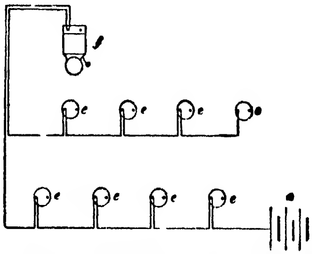


Fig. 64.—Wiring by Looped Joints.

number diminishing by one as each room is passed, and an outlet taken to the push placed there.

As there are no surface obstacles to encounter, and the tubes will be eventually concealed, they can be run close beside the pushes, with standard T-piece fittings for outlets to the push-blocks.

Begin the wiring at the indicator board end by erecting two conduits from a point just above its ultimate position. Use ordinary or "normal" bends when it is required to turn a corner, and the same where terminal outlets are required, as far as possible, unless the tubing comes too near to the surface, in which case short elbows or T-pieces can be substituted. When the runs are fairly straight, with few bends, they can be all erected

and stapled in position to the walls with crampets before the wires are drawn into the tubes; but if there are awkward bends to negotiate, it is as well to "thread" the wires through each length of tubing or fitting as it is put up, to avoid the likelihood of damaging the coverings, as often occurs when drawing them forcibly through a run with many angles and bends. When they can be safely drawn in, however, it is best to do so after the plastering is completed and the condensation dried out of the conduits. In this case, a long steel tape or fish-wire is pushed through the tubes, the bell-wires securely looped to its end, and the whole number carefully drawn through at one time. A special bell-mouth fitting is previously fixed to the end at which the wires enter, and French chalk liberally applied as they pass in. Care is necessary not to exert undue force, as the best of bell-wire coverings is not nearly so robust as that of an electric lighting cable. Choose the shortest runs when erecting conduits, with the fewest possible bends—a comparatively easy matter when the house is in skeleton; also see that the tubing actually enters the blocks to which the pushes, indicator, etc., will be fixed, so that there may be no gaps between, and into which the plaster may find its way, with disastrous effect on the insulation of any wires it may happen to touch.

Push-blocks can be nailed or screwed to quarterings in such manner as to leave their top surfaces just flush with the plaster to be applied later. When, however, there is no suitable fixing, the blocks can be fitted tightly over the end of the tube itself, and provided with bevelled edges, the large diameter being below the surface, so that they may not work loose in the plastering.

The choice of fittings will depend largely on the nature of the subsequent decorations of the rooms. China

pushes can always be used for bedrooms, and are to be obtained in white, cream, or black, with various ornamental and figured covers at prices ranging between 9d. and 2s. 9d. each. All-china pushes are preferable to those having wooden bases, as they have higher insulation and are easier to fit. Wood pushes do not, as a rule, look well, but good serviceable china-base pushes, with stamped or chased metal covers to match the style of the electric light switches, can be had in polished or oxidised brass, copper, silver, etc., and range in price between 1s. 3d. and 2s. 4d. Standard bell wire, No. 20 g., as recommended above, costs about 4s. 9d. per hank of 110 yd.; light brazed Simplex conduit, ½-in. size, 11s. 4d. per 100-ft. run, with necessary sockets; reliable quality 3-in. trembler bells, with platinoid contacts, 4s. each. An 8-hole pendulum indicator will cost 21s., and can be fitted with 3-in. bell on same backboard for 25s. 9d. The charges for writing names of rooms or numbers on the pendulum flags is usually 6d. per hole. The front-door push ought to be of metal, waterproof design, a brass or steel bronzed push of this class costing 2s. 3d. It is a convenience for dining-rooms to fit an extension push, which is similar to an ordinary push, but having two socket holes on one edge into which a corresponding double-pin plug with extension cord and table push fits, enabling a temporary connection to be made to the table at meal times. The set (push, plug, and 3-yd. flexible connection) costs 4s. (All prices in this chapter are pre-war.)

The estimated total cost of material for the bell wiring is set out in the following summary :—

	£	s.	d.
2 3-in. trembling bells at 4s. . .		8	0
4 bedroom pushes, assorted . .		6	0
3 living-room ditto		6	0
1 front door watertight ditto . .		2	3

	£	s.	d.
1 8-hole pendulum indicator . .	1	1	0
Writing on flags		4	0
3 No. 2 Leclanché batteries . .		3	0
1 lb. charging crystals . . .		0	7
120 yd. bell-wire, nine colours . .		5	3
160 ft. ½-in. Simplex conduit . .		17	8
16 T-pieces		4	6
2 bell-mouth fittings			7
8 normal bends		1	10
8 wood blocks for pushes, 2 ditto for bells, 1 shelf for batteries } the lot .		4	0
Crampets, saddles, and nails . .		1	6
Total . . .	£4	6	2

The lighting arrangements will follow closely on the lines indicated before for the bell system, as regards the manner of erection, but the lay-out will be somewhat different. Simplex light brazed tubing of ⅝-in. diameter will be used for this section of the work, fixed to the walls before plastering as before. The electric supply company bring the mains into the house and fix to their fuse-box (see earlier chapters); after this the fittings and the remainder of the wiring is at the expense of the consumer. The company will provide a meter of an approved pattern, to be erected by the consumer, for which a fixed quarterly rental in charged. From the service fuse-box *g* the cables will proceed in the order shown in Fig. 65. The rooms here are lettered from A to M, corresponding to the following order: pantry, drawing-room, hall, kitchen, scullery, dining-room, bedroom No. 1, bedroom No. 2, bedroom No. 3, landing, bedroom No. 4, lavatory, and bathroom. The mains go first to a double-pole switch and fuse *a*, thence to the distribution fuseboard *b*, which should be placed

as nearly as possible in the centre of the lights. One of the cables is left slack enough to be cut at *c* for the insertion of the meter in series with the circuit.

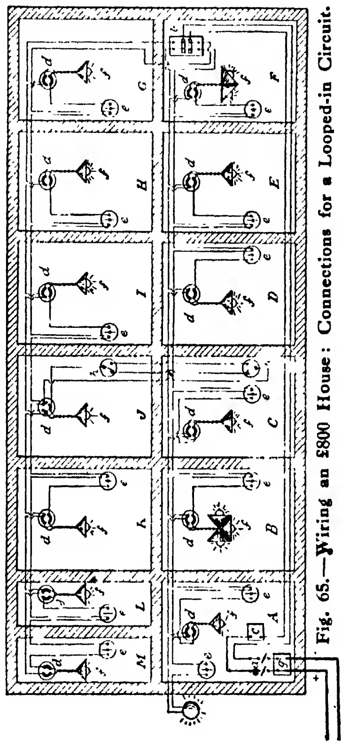


Fig. 65.—Wiring an £800 House: Connections for a Looped-in Circuit.

The position, number, and candle-power of the lamps is now determined, and a schedule drawn up as shown on p. 145.

Metal filament lamps will be used throughout, taking

20 watts each, the total energy required being 17×20, that is 340 watts. A small allowance, say 5 per cent., must also be allowed for losses in the various cables and fittings, bringing the total consumption to about 355 watts. If the supply current is at 110-volts pressure, the maximum current when all the lamps are on will be 355/110, or about $3\frac{1}{4}$ amperes; but if the supply is at 220 volts the current will only amount to half this value.

In either case the cost of wiring will be identical, since wiring rules do not permit the use of very small conductors, the smallest being either a No. 18 S.W.G. solid, or a 3/22 S.W.G. stranded, either of which will safely carry as much as $4\frac{1}{4}$ amperes if need be. The supply company will probably wire their fuses to go at 5 amperes, and the consumer should proportion his main fuses to go at 3 or $3\frac{1}{2}$ amperes, and each branch fuse on the distribution board at half this amount.

For the "feeders" from main switch *a* to the distribution centre *b* it is recommended to use 3/22 stranded cables, and throughout the runs after this a 1/18 solid conductor, except only where pendant lights are employed, when the solid cable is looped in to the terminal blocks of the ceiling rose *d* or switches *e*, and the lamps themselves suspended by 35/40 twin flexible silk-covered wires.

Fig. 65 shows the necessary connections, etc., for a "looped-in" circuit, each light *f* or cluster in each room being under the control of a separate individual switch *e*. If preferred, the wiring may be simplified by making the distribution switchboard control the whole of the lights on each floor, by adding to it a single pole switch as well as fuse, controlling all the upstairs lights, or all the downstairs lights from that point. It is more economical, however, in the long run to have lamps independently controlled, or the current bill at the end of the

quarter is apt to come out heavy. This figure is intended to be diagrammatic only, to illustrate the principle of wiring up. In actual practice the tubes are run in the shortest possible routes from point to point in order not only to save material, but to economise losses in transmission of the current. In this house the best run for the conduit will probably be along the centre of each room, between the floors and ceilings. Outlets are taken by means of T-fittings or inspection boxes down

SCHEDULE OF LAMPS REQUIRED

GROUND FLOOR.	
Porch . . .	One 16-c.p. lamp
Hall . . .	One ditto
Drawing-room .	One 3-light cluster
Dining-room . .	One 2-light ditto
Pantry . . .	One 16-c.p. lamp
Kitchen . .	One ditto
Scullery . .	One ditto
FIRST FLOOR.	
Four bedrooms .	One 16-c.p. lamp in each
Landing. . .	One 16-c.p. lamp
Bathroom . .	One ditto
Lavatory . .	One ditto

TOTAL, seventeen lamps, each of 16 c.p.

each wall to the switch points *e*, and again in the centre of each room to the ceiling roses or lamp fittings *d*. The landing light is arranged so as to be controllable from either floor by two 2-way switches, which is usually found a convenience.

As this necessitates a good many angles in the conduit runs, the threading-in method of running the wires will be the best to employ here. After the various lengths of tube and fittings have been cut off and socketed they are temporarily stapled in position to ensure no alterations are required in lengths, etc. When

all the runs have been completed they are taken down again and laid in correct order on the floors, and the cables pushed or threaded through each length of tube or fitting in proper order one at a time. This is much easier than attempting to draw in the cables forcibly through a long run full of bends. The following is a schedule of material required and an estimate of the approximate cost (pre-war, as already mentioned) :—

GROUND FLOOR.	£	s.	d.
1 d.p. main switch and fuse . . .		8	0
1 3-way distribution board in polished wood case (it is always advisable to allow one spare " way " on the distribution board in view of subsequent extensions being required)		14	0
1 2-light pendant, with shades and lampholders		14	0
1 3-light ditto ditto	1	5	0
1 hall lantern ditto ditto		12	6
1 watertight fitting for outside front door .		7	6
3 assorted pendant fittings, with shades and lampholders complete . . .		18	6
7 terminal fixing wood blocks for switches .		1	9
6 base blocks for ceiling roses . . .		1	6
20 ft. ⅝-in. Simplex light brazed conduit from meter to distribution board . .		2	7
2 ⅝-in. normal bends for ditto . . .			7
100 ft. ⅝-in. conduit for ground floor circuit		12	8
6 ⅝-in. normal bends		1	9
11 T-fittings		3	6
7 ordinary tumbler switches . . .		9	4
1 2-way ditto for landing . . .		2	6
2 ceiling roses for pendants . . .		2	0
10 metal filament lamps	1	7	6

FIRST FLOOR.	£	s.	d.
2 plain brass brackets, 6-in. projection, with shades and holders		5	6

	£	s.	d.
5 pendants and fittings complete . . .	1	11	6
9 fixing blocks for switches, etc. . .		2	3
5 ditto for ceiling roses		1	3
90 ft. $\frac{5}{8}$-in. Simplex conduit . . .		11	5
5 normal bends		1	6
12 T-fittings		3	10
6 ordinary tumbler switches . . .		8	0
1 2-way ditto for landing light . .		2	6
7 metal filament lamps		19	3
Saddles, crampets, and nails . . .		3	0
20 yd. 3/22 cable for mains . . .		4	2
160 yd. 1/18 ditto for sub-mains (allowing for looping)	3	0	0
Total . . .	£15	19	4

Use red-covered cable for the positive wires and black for the negatives, of the class known as 600-megohm grade. Where a conduit comes down a wall to a switch point sunk under a shallow layer of plaster, it is sometimes convenient to use an *oval* tube to avoid the round tube projecting above the surface of the plaster. Special fittings are made to adapt from rounds to ovals in such cases.

The conduit should be erected and the wiring completed before plastering is done, any ends of wires left out being protected against coming into contact with the plaster.

The fittings themselves, such as ceiling roses, switches, etc., are not fixed until the decorations are completed. Insulation tests, as described in Chapter IX., are then made.

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